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FORSCHUNGSPROJEKT DFG
MOHENJO-DARO

G.URBAN M.JANSEN (HRSG)

DOKUMENTATION IN DER ARCHÄOLOGIE
TECHNIKEN METHODEN ANALYSEN

VERÖFFENTLICHUNG DER SEMINARBEITRÄGE
5.–6. DEZEMBER 1981 AACHEN

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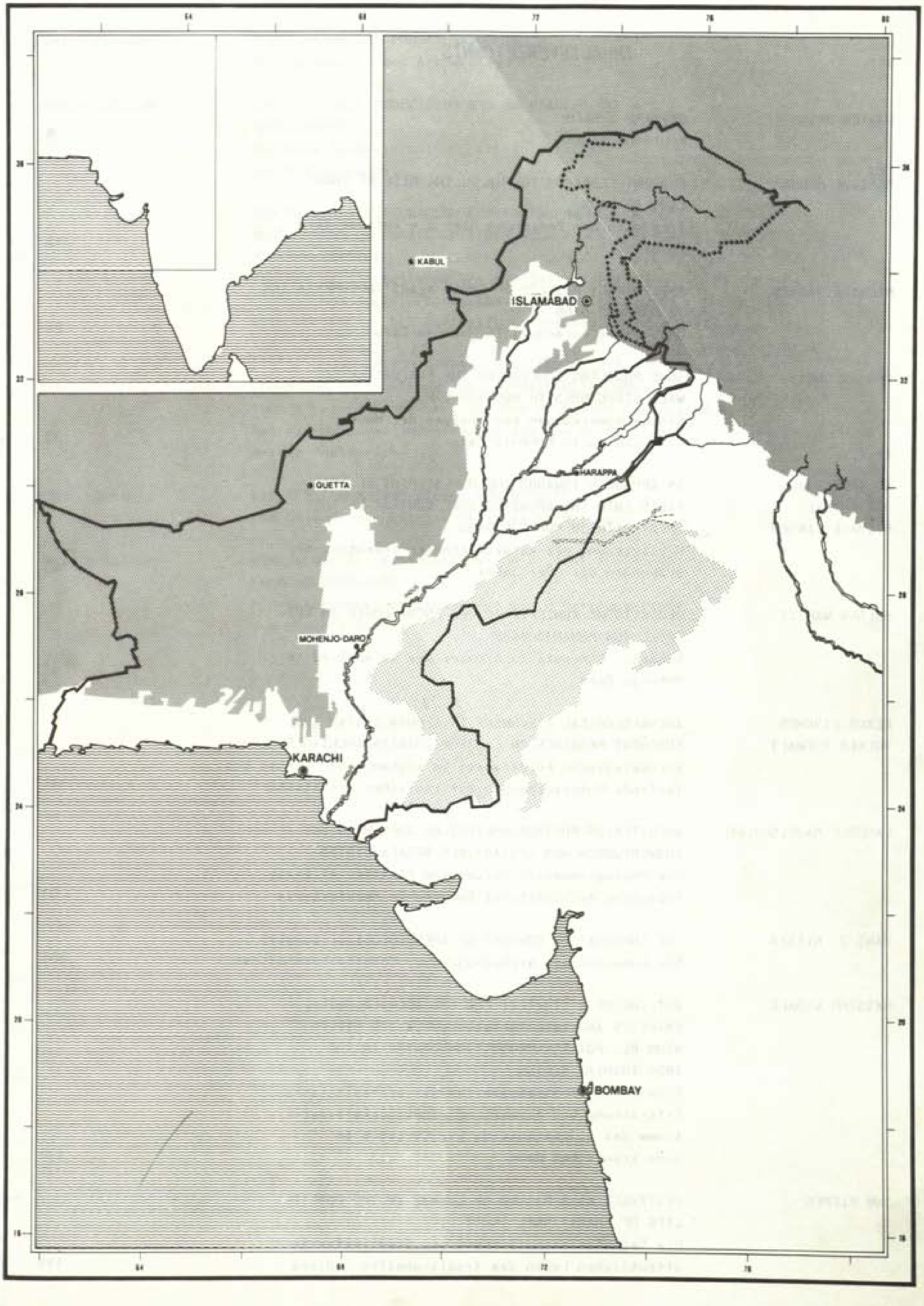
KABUL
ISLAMABAD
QUETTA
HARAPPA
MOHENJO-DARO
KARACHI
BOMBAY

INHALTSVERZEICHNIS

GÜNTER URBAN
REKTOR DER RWTH AACHEN
LEHRSTUHL FÜR BAUGESCHICHTE UND DENKMALPFLEGE
FORSCHUNGSPROJEKT MOHENJO-DARO
RWTH AACHEN

OPENING SPEECH
ERÖFFNUNGSREDE

Ladies and Gentlemen,

In the name of the RWTH Aachen, one of the largest Technical Universities in Western Europe, I have great pleasure in welcoming you all to the Mohenjo-Daro seminar. Although it was arranged at such short notice, I am delighted that so many of our colleagues managed to come in spite of their many duties.
I would particularly like to welcome our honoured guest this weekend, Dr. Mohammed Rafique Mughal, Karachi. At present, Dr.Mughal is carrying out research work at the National Museum in Bahrain and came all the way to Aachen specially for this seminar.
I would also like to say a warm word of welcome to all the others who had to travel long distances in such bad winter weather in order to be with us, and of course to our colleagues from various departments of our university who are present in large numbers.
In this connection I want to express my sincere thanks to the staff of the Department of Geodesy for letting us use their seminar room as a lecture hall and for offering to demonstrate the use of their photogrammetric equipment this afternoon.
Prof.Hektor has also very kindly put the top floor of this building at our disposal,and tonight it will be turned into a reception room with a view of Aachen by night.

Before going on to outline the general aims of the seminar, I would like to say a word about the Mohenjo-Daro Project in the context of the Technical University of Aachen.
True to its name, our university is strongly orientated towards technical subjects and we are proud of its reputation in many fields. It is only in relatively recent times that the humanities have also found a place in the curriculum, and in my official function as Vice-Chancellor of the university, "Rektor" in our language, I am naturally interested in encouraging interdisciplinary cooperation between the arts and sciences. The Mohenjo-Daro Project is a good example of such cooperation which promotes academic tolerance on both sides.
The Departments of Mineralogy, Mineral Mining and Geology have all offered their assistance to the Project in one form or another. I already mentioned the practical help given to us by the Department of Geodesy in organizing this seminar; but it must be mentioned that our learned colleagues have also shown great academic interest in the project over the past two years and the papers read during the seminar will be included in one of their series of publications.

However, I am not only here as Vice-Chancellor of a Technical University with a keen interest in promoting understanding between the various fields of learning but also as the chairman of the Mohenjo-Daro Research Project. It is with great personal interest that I have followed the development and expansion of the Project from very modest beginnings to its present stage, where interdisciplinary cooperation has become not only desirable but absolutely

necessary. Therefore I am delighted that the seminar has attracted so many guests from other departments and institutions, and I hope that the Project may profit from further contacts made during this seminar.

Apart from providing a forum for interdisciplinary discussion, the seminar also gives the Project members the opportunity to show how far they have proceeded with the share of work they are responsible for and to explain their results at this mid-way stage. Discussions with experts engaged in other fields is necessary because the Project has grown more ambitious in its aims than anyone could have foreseen.

Our initial aim was simply to document the present state of the excavated architectural remains in Mohenjo-Daro. This undertaking lay within our technical and organisational capacity and, indeed, the documentation of the site is still our foremost aim. However, work on the site in Pakistan soon showed that things were not so simple and that additional investigations would be necessary in order to complete the documentation.

First, we discovered that the excavated structures had decayed so much that a chemical analysis of the salt content of the bricks would have to be carried out. Secondly, the existence of craftsmen's work areas revealed by surface survey and the poor present condition of the surface itself mean that a tethered hot-air balloon will have to be used for taking aerial photographs of the site. Thirdly, new finds on the surface need to be documented and interpreted from the archaeological point of view. For these reasons we have turned to experts in photogrammetry and archaeology for help. Fourthly, we rediscovered the field registers drawn up by the early excavators of the site in the 1920's, and we hope to discuss with our learned guests the possibility of working together on an analysis of the primary positions of the registered artifacts in order to learn more about their relationship towards the structures concerned and their functional interpretation, should we get the necessary permission from the Pakistani Government to do so. Fifthly, the results of recent investigations in the area around the excavated section show that Mohenjo-Daro is far larger than we had thought.

These are the main reasons why the Project has expanded so much over the years.

Up to now our photographic documentation has been making satisfactory progress and today I am in position to present the first part of our microfiche publication which will comprise about 15,000 photographs altogether. We also plan to publish a monograph on Mohenjo-Daro in the near future. As I have already mentioned, the Project is at a mid-way stage and we can only present the results we have achieved so far.

The third phase of our work in Pakistan will start in January 1982. During this season, we aim first to finish correcting the material collected so far, secondly, to document the Stupa area, and finally to start a surface analysis under the direction of our Italian colleagues. In the fourth season, then, we plan to examine the DK-G area. If everything works out according to plan, we hope that by 1984 we will not only have collected all the data we need but that it will also have appeared in print.

While still on the subject of work in progress, I would like to mention that our honoured guest, Dr.Mughal, has discovered about 300 "new" Harappan sites in Bahawalpur. We are looking forward to learning more about his discoveries which may show that the whole Cholistan region might have been one of the principal formative and mature Harappan settlement areas.

One of the main difficulties archaeologists encounter is the lack of adequate accommodation on sites which are often very far away from the nearest village. As Pakistan is no exception in this respect we plan to build a small house in

Mohenjo-Daro where archaeologists can work in suitable conditions. We hope that this house will one day become the centre of Harappan research and attract local interest in the ancient culture of the area./1/
To further this aim we also plan to organize an instruction course in Pakistan to train local architects and archaeologists in the use of special methods of documenting historical structures. The organisation of this training course will be discussed in more detail at a seminar to be held in Karachi in March 1982 on the preservation of historical structures in that city.
This seminar will be financed by the Goethe Institute and partly organized by the Pakistani Society for the Preservation of Muslim Heritage.
I might also mention an exhibition we are holding in Karachi in February 1982 on the results of our documentation of the ancient site of Thatta./2/

Ladies and Gentlemen,
I may close by expressing the hope that not only the members of the Mohenjo-Daro Project will benefit from the stimulating lectures and discussions in store for us, but that our guests, too, will leave Aachen with a sense of a weekend profitably spent.
The interdisciplinary and international cooperation which I referred to so often can, in our opinion, be best promoted through a seminar such as this.
On this note, I wish the seminar every success.

NOTES

/1/ In the meantime the German Research Project 'Mohenjo-Daro' received the permission to use the local Pakistani Tourist Board Centre bungalow as a research house.
/2/ The proceedings of this seminar will be published by the Goethe Institute, Karachi.

Meine sehr verehrten Damen, meine Herren,

1870 heißt es in unserer Gründungsurkunde: die Technische Hochschule Aachen hat eine interessante und wichtige Aufgabe zu erfüllen: die Aufgabe, das vermittelnde Glied zu werden zwischen Wissenschaft und Praxis, zwischen dem Quell des Wissens, ungebeugt durch Schwierigkeiten drinnen und den verschiedenen Zweigen der Gewerbsamkeit und Technik draußen.

110 Jahre sind seitdem vergangen, doch die damals formulierte Aufgabe ist in ihrem Kern vorhanden und lebendig geblieben. Man sagt, daß ein Land ohne Geschichtsbewußtsein wie ein Meensch ohne Gedächtnis ist - übertragen auf die Geschichte unserer Hochschule heißt dies: Geblieben ist im Bewußtsein das Problem der Erkenntnissuche und seiner Eingrenzung.
Niemand wird den Menschen als ein denkendes Wesen daran hindern, das Erkennbare zu nennen, zu versuchen, doch sollte es unser aller Aufgabe sein, die Freiheit der Wissenschaft und Forschung in ein Verhältnis zur Bewahrung der allgemeinen Freiheit zu setzen.
Das aber sind Einsichten, die letztlich die bis in die Frühzeit der Universitates selbst zurückreichen, also bis um 1200, als in Bologna und Paris die Mutter-Universitäten aller europäischen Universitäten entstanden. Und seit dieser Zeit wird über Leistung wie Elitenbildung diskutiert. Es steht außer Zweifel, Fortschritt in der Wissenschaft entwickelt sich zunächst durch die Leistung des Einzelnen, der den Durchbruch in unbekanntes Neuland erzielt.

Dahinter steht die Erkenntnis eines bewußten Willens zur Qualität. Nur Qualität erzeugt wieder Qualität; Mittelmaß höchstens Mittelmaß oder noch schlimmeres.
Q u a l i t a s , so verstanden, beinhaltet Wissen und Gewissen zugleich, Freiheit und Verantwortung. Hier hinein mündet die neue heutige Form der wissenschaftlichen Teamarbeit.
Es klingt noch heute tröstlich, und wirft ein bezeichnendes Licht auf jene, so

oft gerügten Jahrzehnte des ausgehenden 19. Jahrhunderts, daß bei der Emanzipation der Technik, die im Bewußtsein der Gesellschaft wesentlich zum Verständnis eines Ausbaues Technischer Hochschulen beitrug, der theoretische und praktische Teil des i n g e n i u m s Modellieren und Malen, Entwerfen und Zeichnen als praktische, Kunstgeschichte und Baugeschichte samt antiker Architektur als historische Grundlagen wie selbstverständlich in den Ausbildungsprozeß unserer TH vom ersten Jahr der Gründung integriert wurden - im Sinne von u n i v e r s i t a s , als Einheit in der Vielfalt.

IN NECESSARIIS UNITAS
IN DUBIIS LIBERTAS
IN OMNIBUS CARITAS

IM NOTWENDIGEN EINHEIT
IM ZWEIFEL FREIHEIT
IN ALLEM VERSTÄNDNIS

M.RAFIQUE MUGHAL
DIRECTOR EXPLORATION
ARCHAEOLOGICAL SURVEY OF PAKISTAN

CURRENT RESEARCH TRENDS ON THE RISE OF INDUS CIVILIZATION

TRENDS IN DER FORSCHUNG ÜBER DIE ANFÄNGE DER INDUS-KULTUR

ZUSAMMENFASSUNG

Intensive Grabungen und Oberflächensurveys vor allem während des letzten Jahrzehnts an alten und neuen Fundorten wie Kot Diji, Amri, Kalibangan, Gumla und Rahman Dheri im Indus Gebiet machen eine grundlegende Revision der bisherigen Annahmen über die Ursprünge und Anfänge der Indus-Kultur notwendig.

Die Auswertung des Kot Diji Materials (vor allem Keramikreste), das stratigraphisch und chronologisch (C-14 Untersuchungen) mindestens 500 Jahre früher anzusiedeln ist als das der maturen Phase der Harappa-Kultur (2400-1900 v.Chr.), zeigt eine Kontinuität der kulturellen Traditionen von den tieferen Kot Diji Schichten bis zu den oberen Schichten der Harappa-Kultur.

Dies beweist nicht nur, daß die Kot Diji Siedlungen eine frühe Entwicklungsstufe (formative Phase) der Harappa-Kultur und nicht eine von dieser Kultur losgelöste Vorstufe darstellen, sondern auch, daß das Industal einen eigenständigen Kulturraum darstellt, der ohne die Einflüsse anderer Kulturen entstand und sich entwickelte.

Few sites in South Asia have become as much focus of discussion as that of Kot Diji in the last few years. Ever since the excavations at Kot Diji nearly thirty years ago /1/, this small site has continued to figure in the conceptional approaches to the origins of civilization in the Indus Valley. The archaeological evidence pertaining to the earliest or first settlement at Kot Diji which was originally labelled "Kot Dijian", has become a basic frame of reference for reconstructing a relative chronology of the early sites of the fourth and early third millennia B.C. in the Greater Indus Valley, drained by the Indus and its present and former Tributaries including the now dry Ghaggar - Hakra rivers /2/.

Our knowledge on the Kot Diji material relics - especially ceramics and their geographical extent - has increased considerably due to further explorations and excavations, but the type-site has yet to be reinvestigated although most of the new evidence is being compared with Kot Diji.

It is felt that a fresh review of the known evidence as published by the excavators and the results of further analyses is necessary in the context of development of various conceptual approaches to the rise of the Indus Civilization.

The visible remains of Kot Diji cover an area of 600'x500' approx., which includes a fortified mound 'A' (citadel) of 40' height and an adjoining unwalled area called 'B' (lower city). During three and a half months of excavations in 1954 and 1957 by Dr.F.A.Khan, an area of 24.800 sq.ft. was exposed which constitutes nearly 1/10th of the site.

Deep diggings carried out down to the natural bed rock established that the

existing 40' height of the citadel mound consisted of two major occupations:

1. An early 17' thick deposit containing distinctive Kot Dijian pottery and associated materials with structures of mud and mud-brick including a strong fortification wall built on stone foundations; and
2. cultural layers of 23' thickness, above belonging to the mature stage of the Indus civilization contemporary with the known levels of Mohenjo-Daro. The earliest or first settlement below layer(4) - called Kot Dijian - is our primary concern in the present context.

Two Radiocarbon dates from one of the deep trenches dug at the citadel mound placed the Kot Dijian occupation between 2590 and 3155 B.C. (with MASCA corrections).
The earliest layers of the settlement outside the fortified area correspond in time with the middle Kot Dijian levels and were dated 2805 - 2885 B.C. /3/.
No C-14 date is available for the upper Mature Harappan occupation at Kot Diji but its contemporaneous materials at Mohenjo-Daro are dated between 2060 and 2583 B.C.
Thus, the Kot Dijian occupation turned out to be at least 500 years older than the fully urbanized stage of the Indus Civilization as represented at Mohenjo-Daro.

The beginnings of the Kot Dijian occupation could be dated even earlier than 3155 B.C. because the Radiocarbon date comes from layer(14) which is located above two occupations at the bed rock. It is furthermore pointed out that the Kot Dijian wheelmade pottery is found in few numbers as intrusive element in the mostly handmade pottery assemblage of the first period IA at Amri, located in the south-eastern part of Sind on the right bank of the Indus River.
The second period IB above at Amri is dated by Radiocarbon to 3540 B.C. (TF-864).
Therefore, the earliest period IA at Amri, containing characteristic Kot Dijian pottery forms and surface treatment must be earlier than the middle of the fourth millennium B.C. It is possible that the early stage of the Kot Dijian material traits appeared in the Greater Indus Valley much earlier than previously thought, extending back to the first half of the fourth millennium B.C. but sufficient evidence is still awaited.
The C-14 dates and stratigraphical evidence confirmed the the chronological priority of the Kot Dijian contents which characterized the Indus Civilization in its mature stage. Further analyses of the artifacts and ceramics enabled the author to recognize more Mature Harappan traits in the material culture existing during the Kot Dijian period nearly a millennium before the rise of Mohenjo-Daro and Harappa /4/.

Such traits are particularly expressed in pottery forms and decorative designs, terracotta objects, stone tools and architecture.
In pottery, the most significant examples are:

1. offering-stands of tall and squat types;
2. pans with incurved rim and slipped internally, with or without a wide band painted below the rim;
3. storage jars with out-curved rim;
4. ring-stands;
5. cylindrical vases and those with carination near the base;
6. red-slipped and thin-bodied vases with pedestalled base.

Even the shape of a wide-shouldered pot with 'horned deity' motif seems to have continued in the Mature Harappan period. In addition to the red slip and use of black paint, intersecting circular and fish-scale designs also occur on the Kot Dijian pottery.

Thus, most of the Kot Dijian pottery types are those which continued to remain in use during the Mature Harappan period with similar shape, fabric, colour, technique of manufacture and even surface treatment.

The most distinctive type of pottery named after the site consists of globular vessels with flat base and short rim, painted on the neck with mostly black colour and occasionally with varying shades of red. Its external surface is either plain or red slipped. Comparable examples have been found at other contemporary Kot Dijian sites in Pakistan and India with similar short neck and globular shape. Their external surface is subsequently treated with series of horizontally drawn thin grooves. The other recurrent type are vessels with a prominent flange around the neck (intended to receive the lid) and often painted with black on red or rarely on buff slip.
These two ceramics and their variants have now become diagnostic Kot Dijian types for identification, comparisons and spatial distribution in the Greater Indus Valley /5/.

The emergence of Harappan cultural traits more than 500 years before the mature phase or full urbanization in the Greater Indus Valley and their recognition as integral part of the then civilizational process by the author (1970) induced him to re-study other categories of cultural materials from Kot Diji to confirm the evidence derived mostly from the ceramics. The results were consistent with the evidence of pottery.
The statistical data gathered from Kot Dijian and Mature Harappan levels revealed that steatite seals, cubic weights and Indus script in particular emerged or developed with the fully urbanized stage of the Indus Civilization Though cult objects like female figurines are present throughout, the style of representation changed only during the Mature Harappan times. Some differences in the size of stone tools is also noticeable, indicating a separate tool making industry though the tradition persisted from the lower (Kot Dijian) levels to the upper or Mature Harappan period.
Such flint knapping factory sites have been identified near Kot Diji a long time ago /6/. Humped bull figurines with large horns are found in Kot Dijian contexts but in the upper Harappan levels their representation becomes stylized.
Despite these differences in minor objects, the most significant fact is that all other categories of materials from the Kot Dijian levels are precisely the same as those found in Mature Harappan levels, such as terracotta 'cakes', cones, toy-cart frames and wheels, bangles of red and grey colour, parallel-sided chert blades and cores. Moreover, objects of bronze, beads of carnelian, stone balls etc. also occur in the Kot Dijian and Mature Harappan periods.

Considering the entire evidence of various ceramic types and other materials at all levels of Kot Diji, the author was led to the conclusion that Kot Diji represents a continuity of cultural tradition from the lower Kot Dijian to the upper Mature Harappan levels. Both the assemblages are intimately related as products of one continuous cultural process. In this sense, The Kot Dijian cultural materials, both chronologically and culturally, constitute an Early Harappan or formative stage of the Indus Civilization. The 'burnt' layer separating the two occupations does not indicate a cultural break because as already noted, most of the cultural traits inherent to the Mature Harappan period are found in the Kot Dijian levels as well.

The delineation of an Early Harappan stage and its definition in 1970 was a major change in the conceptual frameworks having been presented since the discovery of the Indus Civilization /7/.
Earlier, Sir John Marshall, V. Gordon Childe and Sir Mortimer Wheeler while realising that the Indus Civilization in form represented an individual or indi-

genous character thought that the impetus for or the idea of civilization must have come from the developed centres of civilization located west of South Asia (Iran and Mesopotamia). In 1946, when Wheeler discovered a different ceramic assemblage from the earliest or first occupation at Harappa he thought of it as 'alien', as having nothing to do with Harappa or the Indus Civilization /8/. In fact, it was later recognised as a Kot Dijian settlement.

When Dr.Khan excavated at Kot Diji in the late 1950's, another site called Bhoot or Kalepar revealed identical Kot Dijian pottery. Another site, Kalibangan, located in northern Rajasthan (India) started yielding Kot Dijian types of pottery as a result of extensive diggings by B.K.Thapar and B.B.Lal.
In the south-western part of Sind, J.-M.Casal turned up characteristic Kot Dijian pottery from Amrian contexts dated to the later half of the fourth millennium B.C. Thus, before 1960, intriguing evidence turned up to show that the Kot Dijian settlement did not represent an isolated phenomenon and there were similarities among some pottery types.
Dr.Khan had noted the occurance of certain traits at Kot Diji, especially in the unwalled area and thought that the 'Kot Dijians' were the forerunners of the 'Harappans'. However, the significance of Harappan cultural traits in the context of the rise of the Indus Civilization could not be ascertained because sufficient data were still lacking.

Looking at the new evidence from Kalibangan, Amri and Kot Diji, Wheeler and others thought that these early sites represented village communities which were contemporary with Mohenjo-Daro and that the Harappanlike traits they showed were due to influence from the major Harappan cities. Obviously, the evidence from the early sites was not considered to be part of the urbanization process ; therefore, it was still looked upon as 'pre-Harappan'.

A review of the literature on the subject published before 1970 reflects persistence of the old diffusionary concept or its paraphrase on the origins of the Indus Civilization. Some scholars like A.Ghosh /9/ and B. and R.Allchin /10/ agreed with Dr.Khan that there were similarities in certain pottery types among these early sites but their implications could not be elaborated.
W.A.Fairservis tried to define some early Harappan pottery forms on a different basis, and attempted to reconstruct stages of development but supportive evidence was not sufficient./11/
While various attempts were being made by the late 1960's, the discovery of further Kot Dijian sites in the Punjab and the Gomal Valley added new dimensions to the discussion. A new approach was attempted and analyses of the entire evidence from various excavated and unexcavated sites comprising ceramics, architecture, technology, long distance trade/exchange, environmental variables, features of religious and social organization existing before the mature stage of the Indus Civilization or before 2500 B.C. convinced the author that processes of urbanization in the Greater Indus Valley had started during the fourth millennium B.C./12/ The evidence from several sites clearly demonstrated that the first settlement of Kot Diji was an integral part of the cultural phenomenon which was wide-spread throughout the Greater Indus Valley with remarkable uniformity of essential elements which later characterized the Indus Civilization in fully developed or urban stage.
The Kot Dijian materials at the type-site and elsewhere in the Greater Indus Valley represented an Early Harappan, early urban or developmental phase of the Indus Civilization./13/
The recognition and definition of the cultural develpoment of the Early Harappan phase having direct bearing on the vital question of the origins and growth of the Indus Civilization was, as already pointed out before, a major change in our understanding of the rise of the Civilization in the Indus Valley.

The last decade of the 1970's was marked by large scale excavations and extensive surveys in the Greater Indus Valley. Their results confirmed and elaborated further on the early cultural development and substantiated its recognition as representing the Early Harappan or formative phase of the Indus Civilization by an overwhelming amount of data. In the Taxila Valley, excavations at the Kot Dijian site of Sarai Khola were completed /14/ and two other contemporary sites, Jhang and Hathial were excavated by the Department of Archaeology and Museums. Further westwards, Prof.A.H.Dani explored the Gomal Valley in the Derajat between the Sulaiman range and the Indus River and recorded a succession of sites including four Kot Dijian sites, namely Gumla, Rahman Dheri, Hathala and Karam Shah./15/
Intensive research started by Prof.Dani at Gumla, continues at another site, Rahman Dheri, by Prof.F.A.Durrani and his colleagues of the Peshawar University./16/ North of the Gomal Valley, Prof.Farid Khan identified at least seven Kot Dijian sites among which two sites, Lewan and Tarkai Qila were excavated by Drs.B. and R.Allchin between 1977 and 1979./17/
Near Harappa, the Kot Dijian occupational levels were investigated at Jalilpur in 1971 and 1976 /18/ and extensive field surveys were carried out in the desert tract of Bahawalpur called Cholistan where 40 out of 414 sites are comparable with Kot Diji./19/
In 1975 and 1977, areas of the Indus Kohistan and Kirthar in southwest Sind were intensively surveyed by Dr.Louis Flam. He carefully examined 72 sites /20/ including those reported earlier by M.G.Majumdar.

Further northwards in the Kachhi plain which is physiographically a part of the Greater Indus Valley, J.F.Jarrige and his international team started excavating at Mehrgarh which yielded an astonishingly long sequence extending back at least to the sixth millennium B.C. and ending with the early Harappan period in the third millennium B.C./21/ Mehrgarh periods V, VI and VII fall within the Early Harappan period of the Greater Indus Valley and northern Baluchistan though beginning could be even earlier in Mehrgarh period IV. In India, the areas originally drained by the Ghaggar - Hakra rivers and their tributaries in northern Rajasthan, East Punjab and Haryana yielded a succession of Kot Diji related sites among which Kalibangan, Siswal, Mitathal, Banawali, Bhundan and Manda were also excavated.

It is obvious that the past thirty years of field research has produced an impressive map of the Kot Dijian settlements in the Greater Indus Valley. The material evidence from numerous sites has itself answered criticisms of some scholars who favoured the traditional approach to this issue. Some of them now feel satisfied and have begun to recognise the Early Harappan stage in the long cultural process of the Indus Civilization.
Dr.F.R.Allchin, who somehow had completely ignored the new conceptual framework ever since it was presented in 1970, has now yielded to the weight of supportive evidence discovered in the Greater Indus Valley including from the sites dug by himself in the Bannu Basin./22/ Dr.Allchin also continued to ignore the new discoveries especially in Bahawalpur, but ironically, he repeats the same arguments which the present author had presented twelve years ago, and admits that the Kot Dijian assemblages do constitute an early Harappan stage, although he always avoided the use of this term in all his previous publications. Perhaps to overcome his embarrassment for not accepting the facts for more than a decade, in some of his previous writings Dr.Allchin tried in vain to work out an idea "similar" to that of the author.

It it further emphasised that the geographical extent of the Early Harappan settlements as revealed by intensive field works started at the beginning of

this decade, almost duplicates that of the succeeding Mature Harappan settlements (Fig.1). The exceptions are the coastal regions and out-posts at Shurtagai in northern Afghanistan and the possible site in Oman which appear to be related with the Harappan trade or exchange. Between Kot Diji and Rohri, at least four protohistoric sites are reported (1982) along the Reni-Nara channel where further explorations would certainly fill up an apparent gap in the distribution of the Early and Mature Harappan sites. It is obvious that the settlements of the Indus Civilization belonging to the Mature or fully urbanized stage utilized the same riparian environment in which the populations of the Early Harappan period were settled.

A considerable degree of craft specialization is reflected by the artifactual remains, a feature already pointed out in 1970. The Kot Dijian settlement is located close to the source of chert where tools in the form of blades were manufactured to be used at a number of settlements. During the Mature Harappan period, Rohri Hills were the major centre of tool making where craftsmen chipped stone tools from where the implements were transported to Mohenjo-Daro and other contemporary sites./23/ Besides the emerging of centres for manufacturing specialised tools, standardization of pottery forms and decorative designs were also achieved during the early period which persisted with further elaboration through the fully urbanized stage of the Indus Civilization. Kilns for firing small objects have been found in association with the Early Harappan sites in Bahawalpur. The shape of the kilns is precisely the same as of those found at Mohenjo-Daro and Lothal.

Semi-precious stones such as lapis lazuli and metal like copper were obtained from from distant sources outside the Indus Valley as attested by their occurance at the Kot Dijian sites. The pattern of long distance trade or exchange which was established during the Early Harappan period was intensified and its sphere was further enlarged in the later period as shown by the location of Mature Harappan sites along the coast of the Arabian Sea.

The representation of terracotta female figurines of identical form and horned motif suggest common religious beliefs or rites throughout the Indus Valley which received further emphasis and elaboration in the succeeding Mature period. The identical form of horned motif on human head has been reported from Sarai Khola, Gumla, Rahman Dheri, Kalibangan and Manda (Kashmir) on the Early Harappan pottery, after its first discovery at Kot Diji. Simple marks or signs engraved or incised on pottery as found at Rahman Dheri appear to represent an early stage of Harappan script.

Thus, the decade of the 1970's as well as the beginning of the 1980's have been most important in bringing about basic changes in old concepts and giving us new understanding of this remarkable civilization. It certainly did originate and develop in the Greater Indus Valley.

The next important question to settle is the process by which changes from the Early to Mature and even later stages took place. It is now time to attempt the reconstruction of the processes which led to full urbanization in the Indus Valley.

FOOTNOTES

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2. M.R.Mughal (1970): The Early Harappan Period in the Greater Indus Valley and Northern Baluchistan (Circa 3000 - 2400 B.C.) Ph.D. Dissertation, Department of Anthropology, University of Pennsylvania, Philadelphia: 15 and 20
3. Lab. No. With MASCA Correction

Lab. No.			With MASCA Correction	
(P-195)	2090	140 B.C	2590 B.C.	Citadel, Layer(4)
(P-196)	2605	145 B.C.	3155 B.C.	Citadel, Layer(14)
(P-179)	2335	155 B.C.	2885 B.C.	Lower City, Layer(5)
(P-180)	2255	140 B.C.	2805 B.C.	Lower City, Layer(5)

4. M.R.Mughal (1970): Ibidem
5. M.R.Mughal (1973): The Present State of Research on the Indus Valley Civilization, Karachi: Department of Archaeology and Museums; and 1974: "New Evidence of the Early Harappan Culture at Jalilpur, Pakistan", in Archaeology, Vol.27(2): 106-113
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12. Note 2 above
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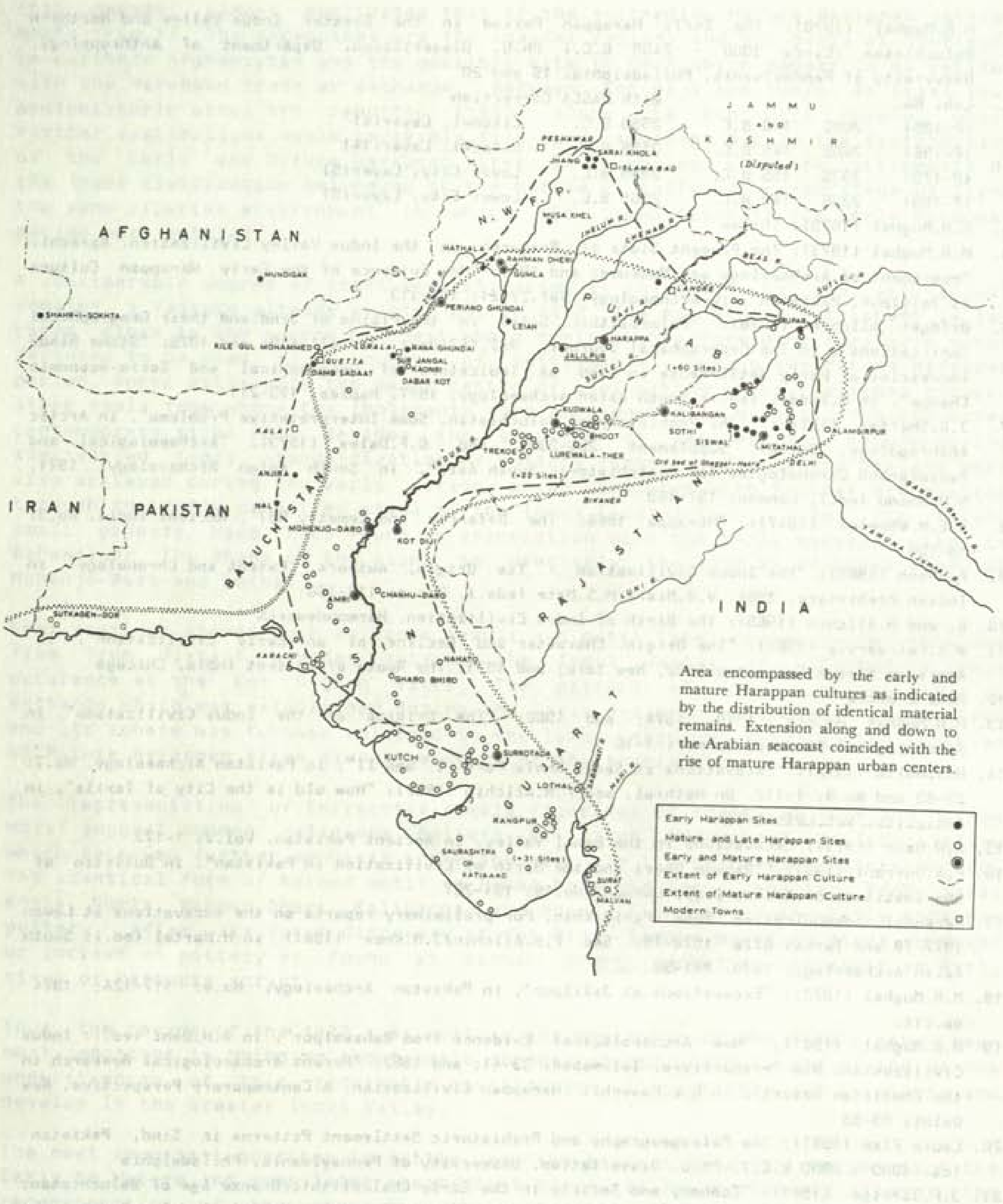
Summary written by C.Müller-Waldeck



Area encompassed by the early and mature Harappan cultures as indicated by the distribution of identical material remains. Extension along and down to the Arabian seacoast coincided with the rise of mature Harappan urban centers.

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FORSCHUNGSPROJEKT MOHENJO-DARO
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PRELIMINARY RESULTS OF THREE YEARS' DOCUMENTATION IN MOHENJO-DARO

Drei Jahre Forschung in Mohenjo-Daro

The German Research Project Mohenjo-Daro has now entered the fourth phase of its planned architectural documentation of Mohenjo-Daro, and about 80% of the structures uncovered by the early excavators have been documented in detail./1/ As the work of the Project is still incomplete, it is not yet possible to present the final results of analyses on the material gathered to date, or to describe new findings of a more general, theoretical nature. The aim of this paper, therefore, is merely to give an account of the course followed by the Project with regard to the solution of a few salient problems./2/

When the Project was planned in 1978 an ideal programme was defined (Appendix I). According to the permission granted by the Government of Pakistan, the Project started in 1979 with a detailed rechecking of the excavated architectural remains of the site. As the excavations basically took place in the twenties, this meant coming to terms with the problem that during the last fifty years the remains have been altered through human and natural agents (see Urban and Jansen/Ardeleanu-Jansen/Franke this volume).Therefore, while documenting the remains, an evaluation under the aspects of original/partly original/not original and not traceable had to be carried out.
Due to the highly destructive nature of the salts (see Ludwig this volume) walls which were rebuilt only a few years ago have eroded so badly that judging by their physical appearance alone they could not be distinguished from the rest. In Moneer site, holes cut into the bottom of the walls to introduce horizontal insulation could only be identified as new with the help of the Authority involved. The decision of the "Authority for the Preservation of Mohenjo-Daro" to use well fired bricks and to mark them with a date was of some help.
Therefore, this structural evaluation was of extreme importance for carrying out a critical architectural analysis as this would have been impossible without the additional data it provided. Under these conditions the original plans and a detailed photographic documentation of the excavations in the twenties became the primary source of the analyses. The fairly detailed architectural description in the publications (Marshall 1931, Mackay 1938) too was of great help. Another stroke of luck was the rediscovery of hundreds of mostly unpublished photographs in Karachi, Mohenjo-Daro and Delhi, a list of which was published in the "List of Archaeological Photo-Negatives. Part I. Corrected up to the 31st March 1935. Stored in the Office of the Director General of Archaeology in India".
The most important addition to our corpus of data was the rediscovery of the unpublished field registers of the early excavations, beginning in 1924 and ending in 1938 (see Jansen et al. this volume). With these data at our disposal, we will be able to carry out an analysis of the architecture from a threedimen-

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/1/ With the phase 1982-83 about 95% have been documented in detail.

/2/ Before starting to describe the progress we have made in documenting the structural remains of Mohenjo-Daro, we would like to express our gratitude to the Director Archaeology, M.Ishtiaq Khan, to our colleagues from the Archaeological Survey, to the Deutsche Forschungsgemeinschaft (DFG), to all the members of our Project, without whose cooperation this paper never could have been written. We wish to thank Dr.M.Mulloy and Cornelia Müller-Waldeck for revising this paper.

sional perspective by relocating the registered objects in their proper contexts.

In order to collect all the available architectural data, the Project decided on a detailed method of relevelling and double checking all of the existing ground plans, as well as a photographic documentation covering each and every wall (see Wanzke this volume)./1/

This method of documentation was developed due to the following constraints:

- The results of each season should represent a unit of its own.
- The final documentation should cover the whole area excavated in the time given (approx. 1.5 days per house unit).
- The documentation should represent an optimized collection of data which would permit a structural functional analysis to be carried out.

With the help of modern techniques in photogrammetry and surveying with a hot-air balloon, the documentation can proceed from a general study to a more detailed analysis, depending on the time available in the field. On the one hand this is complicated by the vast amount of objects to be documented, but on the other it is facilitated by the standard size of the bricks used in the architecture. The prime importance of such a detailed photographic documentation is demonstrated by the fact that since we began our documentation many walls have collapsed, and can now be studied only from our photographs. Fortunately, more than 80% (60,000 square metres) of the structures have already been documented from both general and detailed perspectives.

THE HISTORY OF EXCAVATIONS AND THEIR NOMENCLATURE (PL. 1)

The first notes on Mohenjo-Daro are to be found in a report by D.R.Bhandarkar, Superintending Archaeologist of the Western Circle, who, inspired by the discovery of Buddhist stupas at Mirpur Khas and Thul Mir Rukan (Bhandarkar 1921:4-5) visited the site in winter 1911-12. In his report he expressed disappointment at not finding even one of the carved and moulded bricks that were so abundant at Mirpur Khas. Furthermore, he identified what later turned out to be a part of the stupa core as a tower, and restated the local tradition that the town was not more than two hundred years old.

Although Bhandarkar missed the point by not identifying the Buddhist site at Mohenjo-Daro, not to mention its real ancient character, it is of interest to note the absence of carved moulded bricks that were so typical in the other Buddhist structures in Sind. It is now obvious that the monastery and the adjacent structures were constructed almost completely from Harappan bricks, which the later excavator, R.D.Banerji described as being "of the modern type"./2/

The next recorded visit was made in 1919-20 by R.D.Banerji, the successor of D.R.Bhandarkar. In his report (1921) he correctly identifies the stupa for the first time and mentions the presence of numerous round, hemispherical structures of burnt and sundried bricks, which were most probably the remains of eight circular foundations of votive stupas that can still be seen in the area north of the Great Bath (Marshall 1931: Pl.3). Interestingly enough, he also reports the discovery of "a number of carved bricks" that he found "on another high mound,

/1/ This photographic documentation will be fully published on microfiche by IDC, Leiden (Netherlands) and will cover appr. 15,000 photos.

/2/ Recent studies of the citadel have proved that the extent of the Buddhist remains is larger than described by Marshall. The difficulty of identifying them is due to the fact that these buildings were constructed from Harappan bricks and had the same orientation as the Harappan buildings. Even the technology of brick laying was copied.

which is the second largest in this place".(Banerji 1921: 79-80).
R.D.Banerji conducted a small excavation in 1921-22 on the highest part of the mound, close to the main stupa, which he termed "Stupa 1". The following entry can be found in the first issue of the Annual Reports (ARASI 1922-23, pp.102 following):

Mr. Rakal Das Banerji writes in respect of the excavations undertaken by him: Mohenjo-Daro is the present name of a ruined city which once stood on the banks of the river Indus, when it flowed in an old bed, much to the west of its present course .... The city was built on both banks of the river, but its principal shrines were erected on islands in the middle of it. A cluster of five shrines was built on a group of five islands, lying close together, two of which were excavated during the year under review ...

The finds in Site no.I consist of flint scrapers, cores, bouchers, dice of polished marble and terracotta, fragments of marble chairs, pieces of small images and umbrellas of white marble, oblation vessels of conch shell, bangles and ornaments of conch, beads of various stone, copper and bronze, pipes of carnelian and pottery of various shapes ...

The most important discovery of the season was a seal of soap-stone, found on the staircase on the river side, at the bottom of the eastern retaining wall of the tower./1/ This seal bears in the centre the figure of a one-horned quadruped, which has been identified by Dr.D.B.Spooner as the unicorn. The fragment of a similar seal was discovered on a small shrine to the north-east of Site No.I. These seals bear ideograms or pictograms like the seals discovered at Harappa.

This preliminary note by the discoverer of the site definitely influenced Sir John Marshall in his article entitled "First Light on a Long-Forgotten Civilization" published in the Illustrated London News (pp. 528-32, 48) on the 20th of September, 1924 in which he disclosed R.D.Banerji's sensational find to the western world.
Later however, Marshall dissociated himself so much from Banerji's interpretation of the remains that he did not even include the latter's notes in his first publication. On p.14 (Marshall 1931) for instance, he observed that:

... The remains brought to light by Mr.Banerji in Sites 2 and 3 ... are not dealt with in the present publication, for the reason that their clearance had not proceeded far enough for any tangible conclusions to be reached ... Let me add that in writing the chapter on the Stupa area 1 I have had access to a lengthy manuscript article by Mr.Banerji describing the results of his labours at Mohenjo-Daro in 1922-23. This article not being suitable for inclusion in this work, the author of it was authorized by the government to publish it, if he so wished, independently.

As George Dales so rightly stated in his paper delivered at Srinagar in 1979,
" ... the most serious losses are the reports on the work of Mr.Vats in the VS-area and the report of Mr.Banerji on his work in the Stupa area."

Our Project had the good fortune to relocate Vats' fieldbook, and perhaps our team may be lucky enough to come across Banerji's notes as well. (As regards the terminology it should be noted that the present sites 1, 2 and 3 correspond to Banerji's Stupa 1, 2 and 3.(Pls.2-4)
At least in one respect Banerji's dig of 1922-23 is well documented, namely by the relatively large number of photographs published in the Sind Volumes. Photographs 5016 to 5028 and 6019 to 6032 are to be found in Vol.2, 1916 to 1922, and photographs 6033 to 6096 in Vol.3, 1922 to 1923. Number 6228 and following show views of Vats' 1923-24 dig in Site 4. Number 6303 to 10 show seals unearthed in this excavation.

/1/ Probably the outer retaining wall which can still be seen today.

Under the direction of Sir John Marshall, M.S.Vats' Site 4 was cleared in the following season, 1923-24. A test trench was dug in the south-western area of the eastern mound where Vats carried out further excavation work in the 1925-26 season and which was labelled the VS area.(Pl.5)

In the 1924-25 season K.N.Dikshit started cutting trial trenches A, B, C,C',D and E in the respective mounds NE of the VS section and also test trench F in the "Citadel mound".(Pl.6). The first photographs of these trenches to be published in the Sind Volumes are numbered 6498 onwards for DK-A, 6515 onwards for DK-B, 6529 onwards for DK-C and 6562 onwards for DK-E.
The earliest drawn plans of Site II, areas DK-A, DK-B, DK-C and DK-E were published in Volume V, 1924-25.

The first topographic map of Mohenjo-Daro appeared in 1927 (Pl.6) /1/ There the two clearly distinct mounds are shown for the first time. On the western mound ("Citadel") the areas 1, 2, 3 and F can be discerned, and on the eastern mound Vats' area 4 and Dikshit's test digs A, B, C, D, D' and E. The future HR area can be clearly seen as a topographic feature of its own.

In the 1925-26 season Marshall hired all available talent to launch a large-scale excavation campaign. Among those who took part were the Superintendant of the Frontier Circle, H.Hargreaves, M.S.Vats, K.N.Dikshit, the archaeological chemist, Sahna Ullah (B.L.Dhama) and Marshall's excavation assistant A.D.Siddiqui. Hargreaves dug out the eastern portion of the present HR-area, while the HR-B area was cleared by Daya Ram Sahni in the 1926-27 season. Vats extended his 1923-24 dig as far as First Street and in the same season 1926-27, Daya Ram Sahni excavated the eastern and southern portions. Dikshit extended his dig in DK-B and DK-C and Marshall himself,together with his assistant Siddiqui, dug out the Great Bath and the surrounding structures. A small area north of the Stupa was cleared by B.L.Dhama and accordingly entered as DM area in the registers (under documentation, German Research Project Mohenjo-Daro, Aachen Technical University).
The references concerning the photographic documentation are as follows:
Sind Volumes Delhi, vol.6, 1924-26, nos. 1110-1212, areas DM and SD;
Sind Volumes Delhi, vol.7, 1925-26, nos. 213-336, areas VS and HR;
Sind Volumes Delhi, vol.8, 1925-26, nos. 337-450, areas DK-B and C;
Sind Volumes Delhi, vol.9, 1925-26, nos. 3594-3691, VS-area.
All the photographs taken from 1925 onwards, classified according to areas and numbers, are contained in a single volume published by the Archaeological Survey in Simla and Delhi in 1936 (Cf. Bibliography no.5).

In 1926 Dr.Mackay had been asked by Sir John Marshall to take over the excavations in Mohenjo-Daro as he was already familiar with Mesopotamian excavations. Another reason was that all the officers involved in the large-scale excavations of 1925-27 could not afford to do research work in Mohenjo-Daro any longer due to their survey duties.
In 1926-27 Mackay excavated L area in the southern part of the citadel and a huge building east of the Great Bath. He introduced a new sytem of threedimensional location of objects giving room numbers for the horizontal orientation and absolute heights (bench marks) for the vertical orientation. Still another orientation with an Area/Block/House/Room numbering system was later introduced

/1/ The reference is: Annual Report of the Archaeological Survey of India 1924-25 (ARASI), Calcutta; PLate XVI, Contour plan of ancient sites.

in both publications of Marshall (1931) and Mackay (1938).

In 1927 Mackay started with his excavations in DK-G, taking as a northern limitation trench E which had been cut right across the "Lower Town" by Dikshit in 1924-25. Later on he extended his excavation north of this trench (DK-G north). In his search for further possible fortifications in 1931 he dug several trenches; (Mackay 1938, northern trenches, Pl.VIII) the one which is situated north of the "Lower Town" he named DK-H. It is noteworthy that in 1927 Marshall engaged A.Francis to draw up the first exact topographic plan (henceforth referred to as the Francis plan) of the site. Drawn to the scale of 100'to1" with contours at 5' intervals it was used by both Marshall and later Mackay as a working guide, and this map was published in their articles.

In studying the unpublished fieldbooks of Mohenjo-Daro, two additional excavated areas have been identified. Subsequent research has determined that in 1932-33 and 1935-36 Moneer and Puri conducted an excavation east of VS area, which was recorded in their registers as DK-I area and which we refer to as Moneer site (Jansen in Wheeler Memorial Volume, Delhi, under print, Dales 1982). The other excavation was carried out in the southern extension of DK-B in 1938 /1/ and the register was signed by A.Rahman (26.05.1938). The registers of the antiquities recovered from these excavations have been rediscovered at the Mohenjo-Daro Museum but the provenances of these antiquities recorded with the use of an independent system of room numbers which were not included in the overall architectural plan. So far, no records referring to this system have been traced so the objects cannot be replaced in their proper architectural contexts.
The only other excavations at Mohenjo-Daro were conducted by Wheeler in 1950 and G.Dales in 1964-65. Both await final publication./2/

DATA ANALYSIS

With the completion of the research project at Mohenjo-Daro, it will be possible to correlate all the data described above. It is clear from Pl.7, that these data can be differentiated into two categories, the material objects and their documentation. The former represents the primary source while the latter results from the subjective interpretation of the researcher, whith the consequence that the more complex the material culture, the more selective is its interpretation.

As shown in the graph, material culture as a primary source can be differentiated into that still in situ or dispersed. This differentiation represents the most critical part of our research because the accuracy in recording the exact find spots of different objects was highly unreliable during the earlier excavations. Consequently, unless we have photographs of the objects in situ, we can only reconstruct their original location with the accuracy that the excavators used in recording them. The structural remains at the site can be differentiated into those which are no longer standing and those still in situ. The latter are used as a directly accessible primary source while the former must be critically evaluated according to the documentation available. Eventually, the final aim would be to reconstruct the missing and partially ruined structures on the basis of this detailed scientific analysis, and thus contribute towards the preservation of the site.

/1/ The terminology of George Dales (1982) for Moneer Site as DK-B site could not be proved. There was another small excavation in DK-B north of DK-I site in 1938.

/2/ Through Prof. N.Hammond the original unpublished plans of Wheeler's excavation could be relocated. They are now with the Project at Aachen.

The analysis of the material culture or structures that are still in situ has proceeded according to the parametres set out above. The first, general approach towards the structural interpretation of the architectural remains has resulted in the delimitation of "clusters". Since no stratigraphic sections were recorded during the excavations, the architecture itself is the only structural indicator of horizontal and vertical growth.

A. THE STRUCTURAL CLUSTER

An architectural "cluster" is defined as a system of structural remains directly connected to one another. An area such as HR area consists of different clusters that are separated by non-structural interspaces. For example, House I, HR-A area, is considered as a cluster, which is disconnected by interspaces from other clusters and therefore for the time being can be analyzed only internally. Its centre and its additions can be defined by reconstructing its threedimensional growth, which in turn results in a relative chronology for that cluster.

B. CHRONOLOGICAL CORRELATION OF DIFFERENT CLUSTERS

Before this, the contemporaneity of different clusters could only be demonstrated through structural joints such as drains etc. One example of such an interstructural connection between different clusters can be studied in HR area. Here, in HR-A (House III, Block2) a drain links this unit with the sess pit in First Street.

This drain starts at 57m above M.S.L. in the NE corner of room 15 as a vertical pipe fixed in the wall from where it drops to a drain at 54m. From there it joins another drain in Deadman Lane at about 53.5m and finally ends in the sess pit no.1 First Street at abot 51.5m.

It was only with the help of this drain that the contemporaneity of structures on levels 5.5.m apart and separated horizontally by not more than 30m could be proved, thus allowing otherwise unconnected clusters to be linked.

This example also shows the stratigraphic complexity of the settlement topography which cannot be explained by the horizontal stratigraphy suggested by Mackay and Marshall.

Even within a single structural cluster we could observe a considerable difference in height between otherwise contemporaneous levels.(Pl.9). In HR-A, House I the southern courtyard has an absolute height of 51.60m whereas the northern courtyard, which is reached by a double staircase, is at 53.9m. This difference in height of 2.3m would cover at least three occupational strata according to Mackay's stratigraphic model./1/

The reanalysis of the structural remains in HR area so far indicates that in this part of the site the occupation levels were ascended eastwards, with First Street being the lowest level. A similar terrace-like construction can be traced in VS-A south (Block 1, HouseI,V) where we see a lower structure (50.13m) joined to a higher one (53.10m) by a staircase.

C. CONCLUSION

These examples show quite clearly that Mohenjo-Daro was not constructed in homogeneous horizontal units, but that it grew at different rates, resulting in variable horizontal and vertical distribution of contemporaneous structures.

/1/ Mackay's stratigraphic level model covers 7 strata from the uppermost (Late I, 53.50m a.M.S.L.) to the lowest (Early I, below 48.24m a.M S L.) thus overcoming a height of 5.26m.

Some of these areas may have been separated by deep depressions such as the one south of HR, between HR and VS areas and the one south of DK-G. On the basis of the architectural analysis of HR and VS areas it is suggested that at least the depression between VS and HR is an ancient one and is not the result of later meanders of the Indus River.
Looking more closely at the horizontal growth of HR area, we see various structural clusters which illustrate different growth rates.(Pl.10):
Block 4 (HR-A) shows an almost linear growth extending from North to South, the only exception being House XII, which is opposite the great courtyard (Block 2, House V, HR-B).
Block 1 and 2, on the other hand, show a much more complex growth system. In the southern part of Block 1 there are two older structures that have been enlarged by the addition of new walls and rooms to form a radically altered structure, which undoubtedly served a purpose different from that of the original structures.

As has already been described above, the lower southern courtyard was joined to the upper northern area by a double staircase. There are twin entrances in the south, leading to the lower courtyard, which contains a circular ring of bricks. This circular structure cannot be interpreted as a well, but unfortunately its function has not yet been determined. It has been possible to analyse this conglomeration of old and new building phases through a detailed study of the construction of the various walls and their joints.

In this same manner, we have determined that a spiral growth pattern behind the structures in Block 2, HR-B. Other parts of the HR area are less complex, exhibiting a linear growth which did not incorporate older structures in the process of horizontal expansion.
It is difficult to interpret the dynamics of the various building phases in the case of complex structural growth, but linear growth might indicate the re-building or extension of an area during a single building phase. Spiral or irregular growth can only be seen as the functional adaptation of structures that are confined within an existing building. Other areas which show linear growth are the northern parts of HR-B and Moneer Site (MN-B).
In the latter area another interesting feature is the presence of a special type of structure repeated throughout most of the area.

These few examples demonstrate the necessity to study the architecture of Mohenjo-Daro in terms of well defined micro units. Unfortunately, their relative chronologies cannot be determined by structural comparisons alone, and we hope that the threedimensional relocation of artifacts within the related structures will provide more reliable information for the study of their chronological relationship.
This relocation of artifacts will be done with the help of a specially developed computer programme, which will integrate the architectural documentation with the artifact data obtained from the original field registers.
Hopefully, the architectural documentation will be completed by the end of the winter season 1982-83, after which the computer analysis can be implemented.

THE EXTENSION OF THE DOCUMENTATION PROGRAMME AFTER 1981

In addition to the documentation of the excavated areas we have begun a systematic study of the unexcavated surface areas of the site. This study has resulted in the discovery of numerous concentrations of artifacts that have been classified by Prof. M.Tosi as "craft-indicators".(1981)
Major concentrations have been located north of DK-G area, all along the eastern

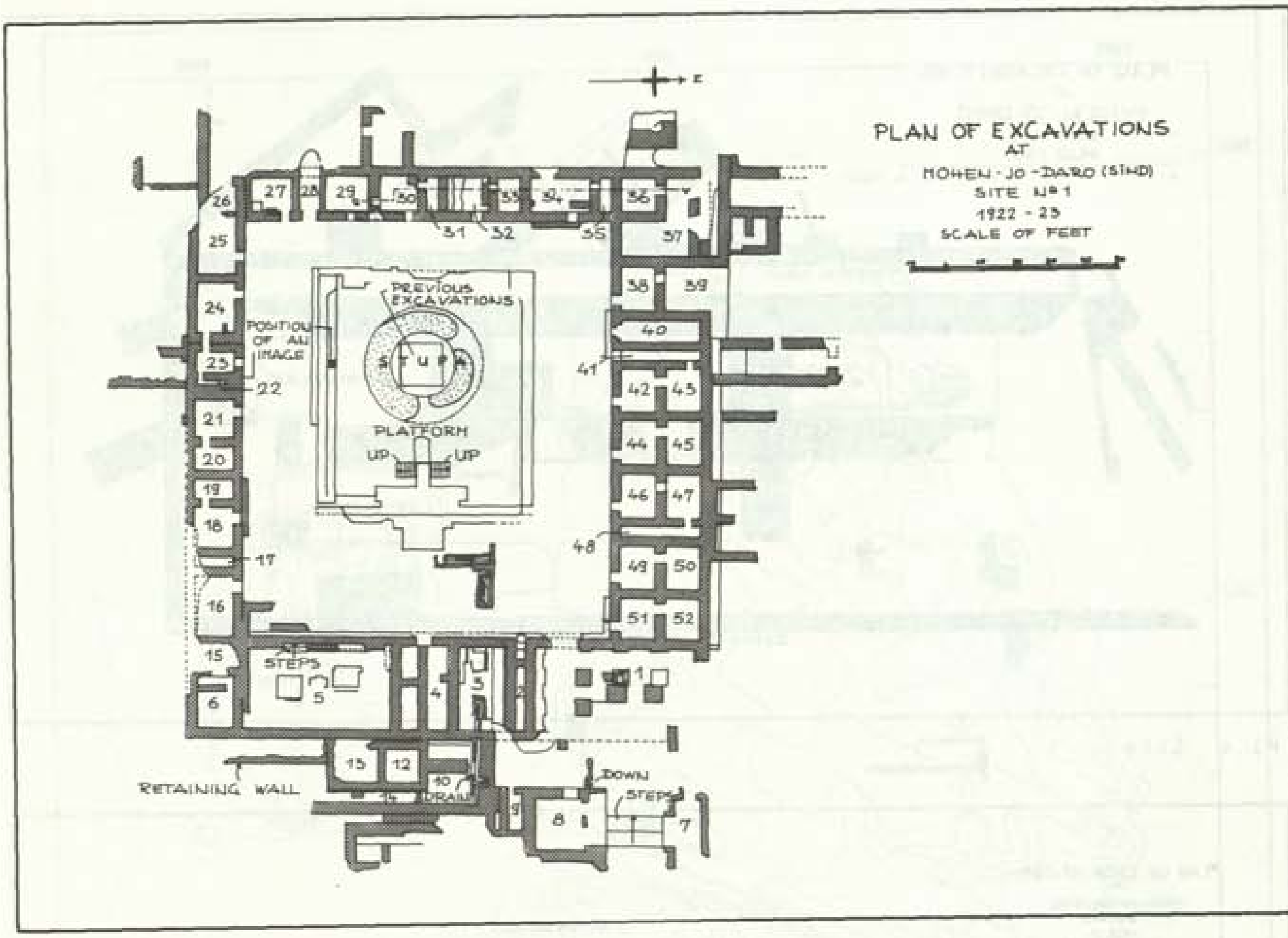
1920

	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	40	50	64/5	AH	RH	M	R	PH
Site 1		?	?																						XX		XX
Site 2		?	?																						XX		XX
Site 3		?	?																						XX		XX
Site 4			?	?																					XX		XX
DK A				●	●																			XX	XX	XX	XX
DK B				●	●													*						XX	XX	XX	XX
DK C				●	●																			XX	XX	XX	XX
DK D					●																			XX		XX	
DK D′					●																			XX	XX	XX	
DK E					●																			XX		XX	XX
DK F					●																			XX		XX	
DK G							*	*	*	*	*												XX		XX	XX	XX
DK H										?															XX	XX	
DK I												*	*		*	*										XX	XX
VS A					●	O																		XX	XX	XX	XX
VS B						*	*																	XX	XX	XX	XX
HR A					●	O																		XX	XX	XX	XX
HR B						*	*																	XX	XX	XX	XX
SD				●	●		*																	XX	XX	XX	XX
DM					O	O																		XX	XX	XX	XX
L						*	*	*	*														XX		XX	XX	XX
Granary																					??				XX		XX
Fortif.																					??				XX		XX
D																						??	XX		XX	XX	XX

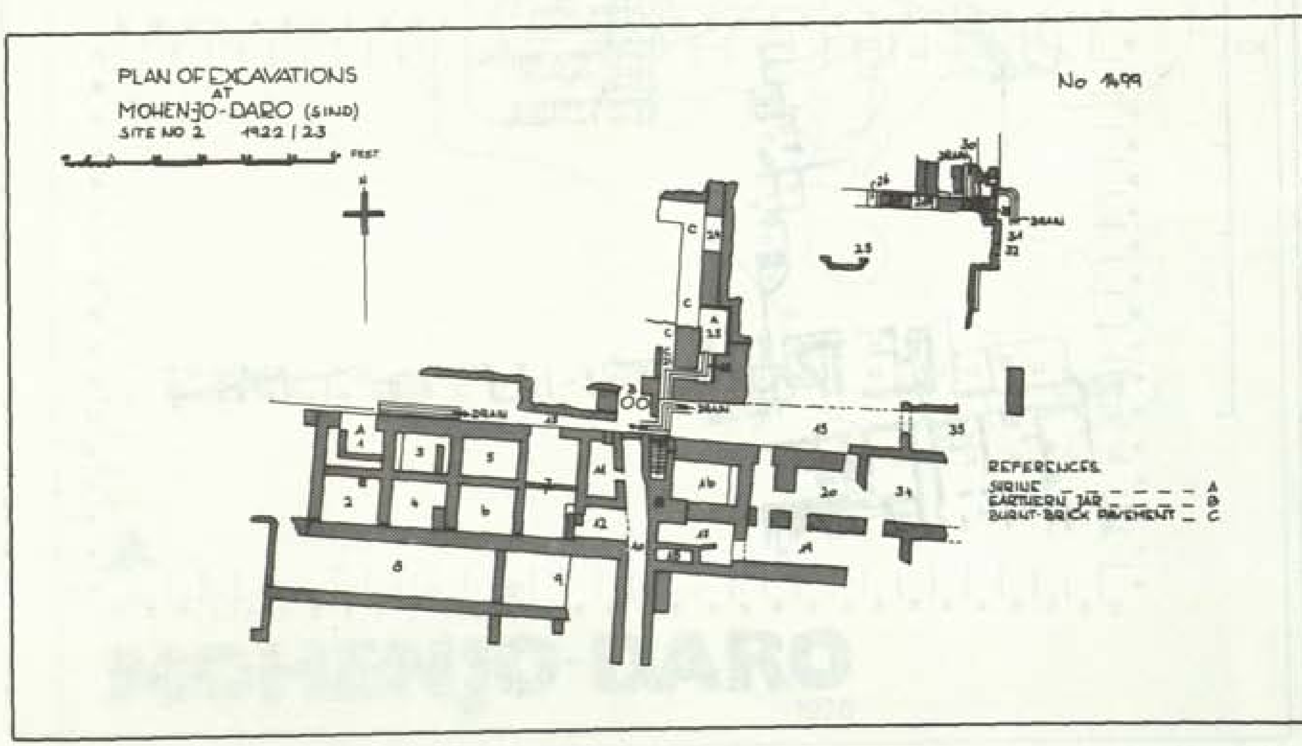
O Feet grid (1200 x 800 / Dikshit)
O 100 feet square grid (24 LL / Marshall)
* Room numbers (Mackay)
? Non identified orientation system

AH = absolute hight
RH = relative hight
M = Maps
R = Registers
PH = Photos

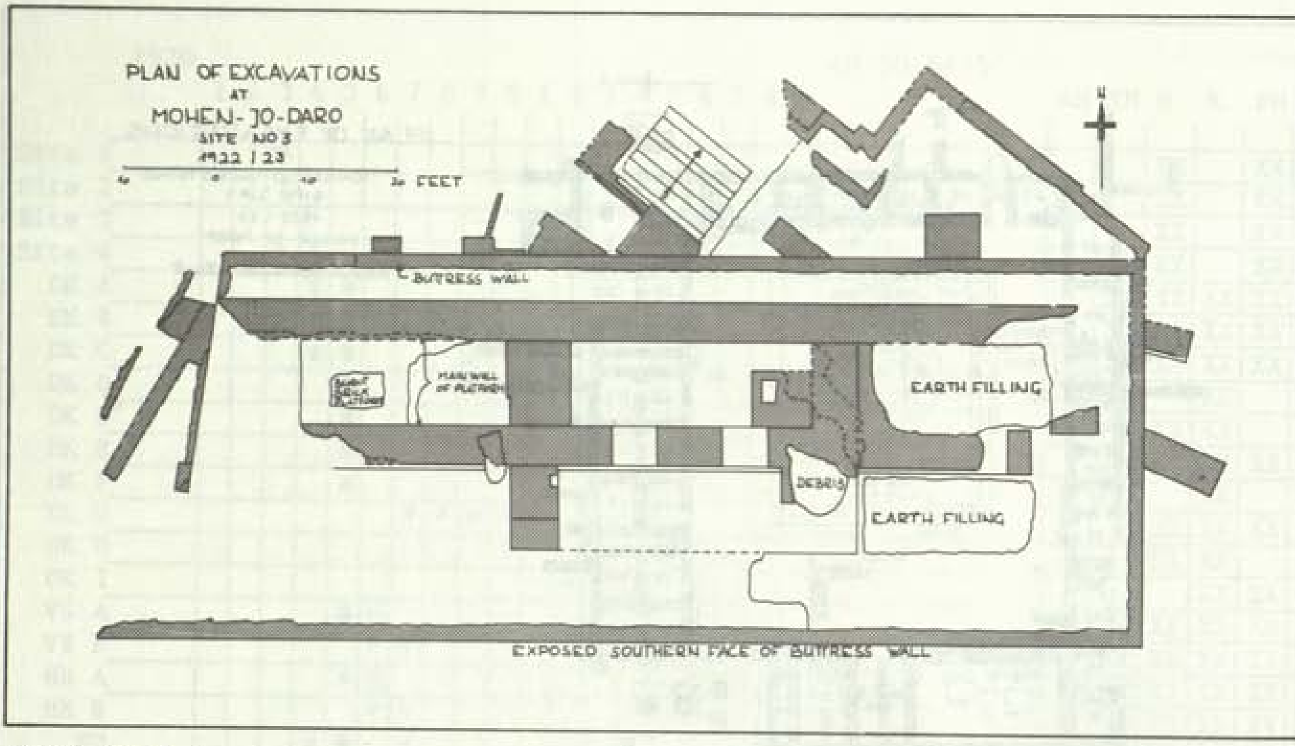
Pl.1 Diagram of excavations showing their time distributions and their sources available



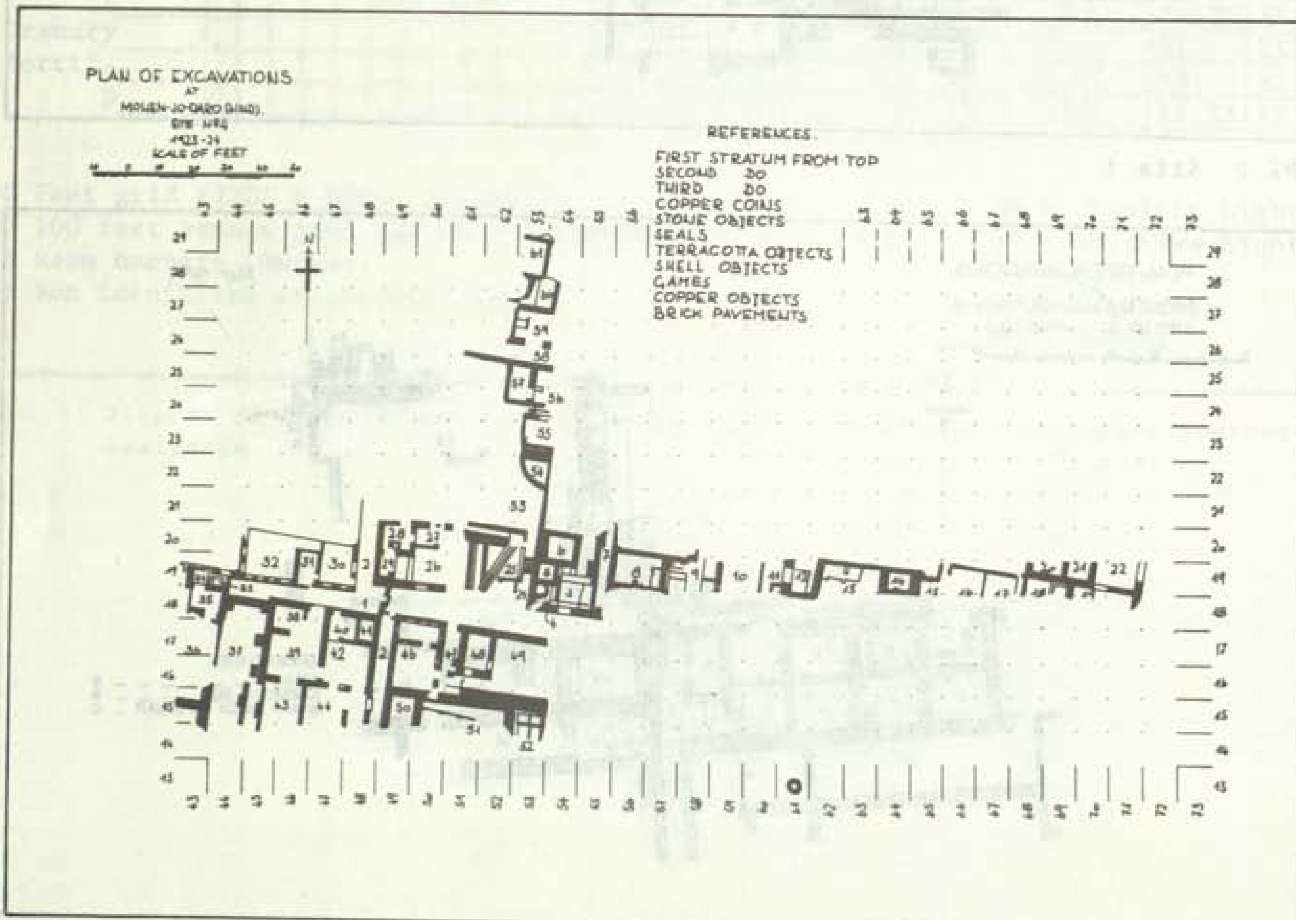
Pl.2 Site 1



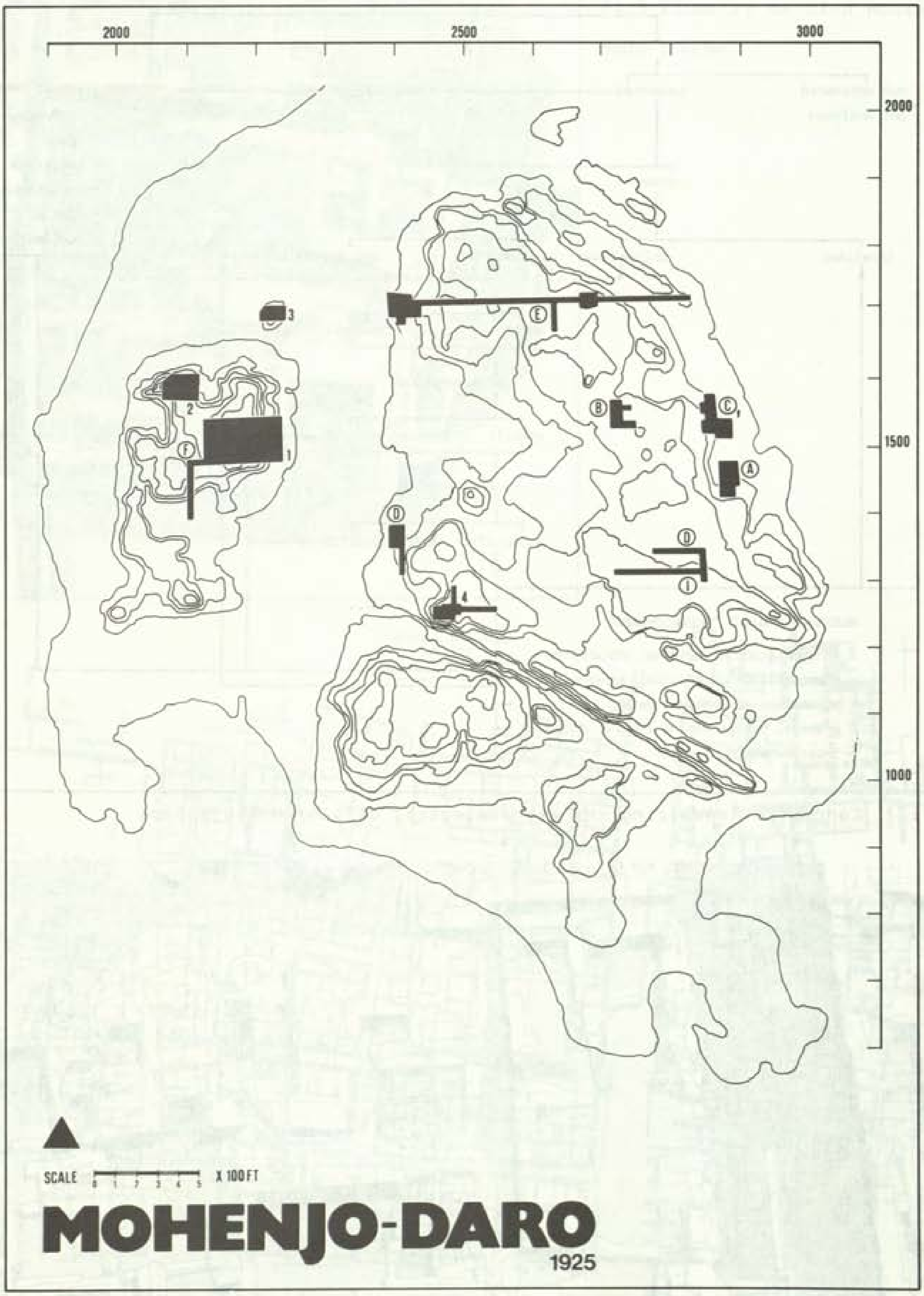
Pl.3 Site 2



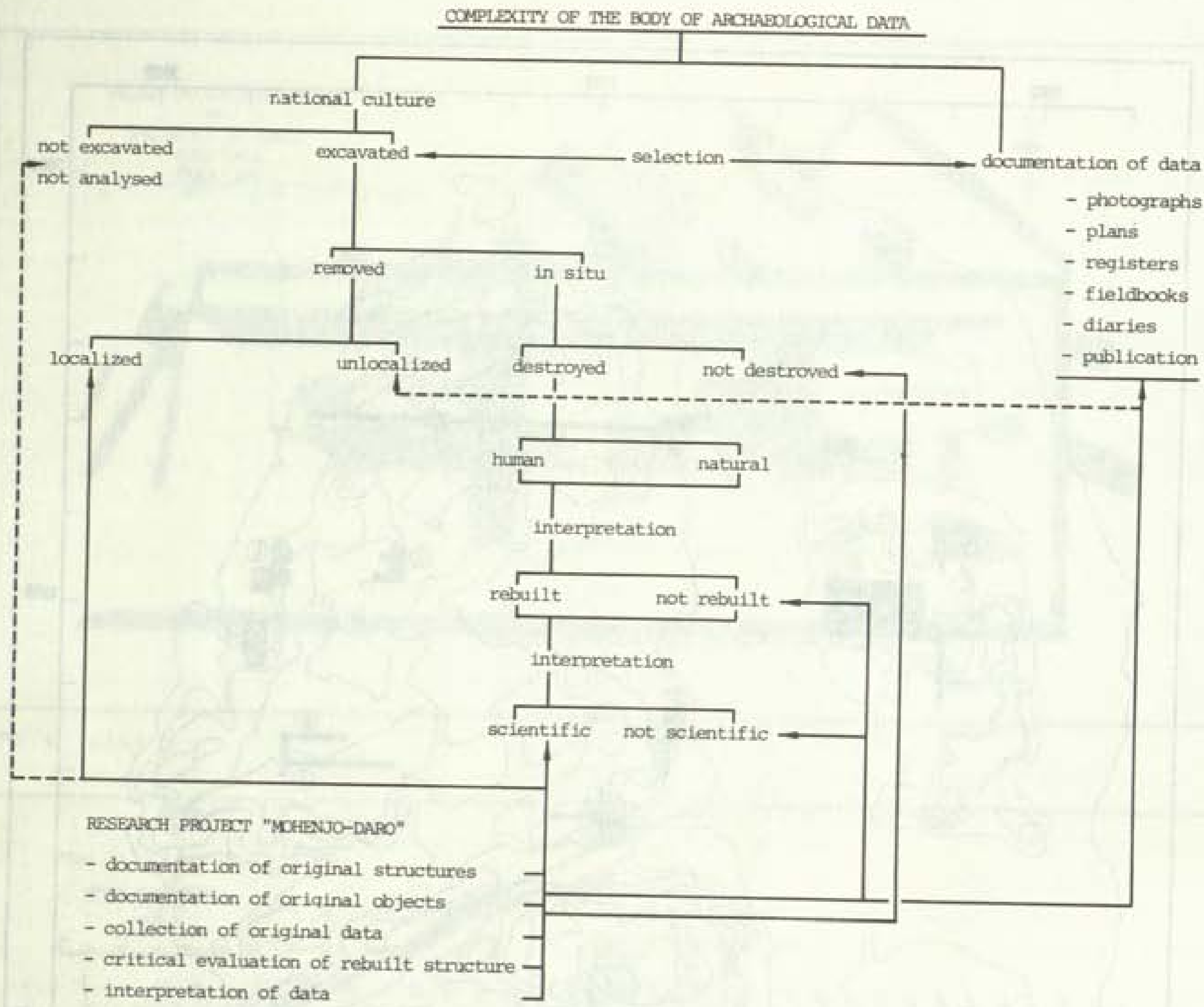
Pl.4 Site 3



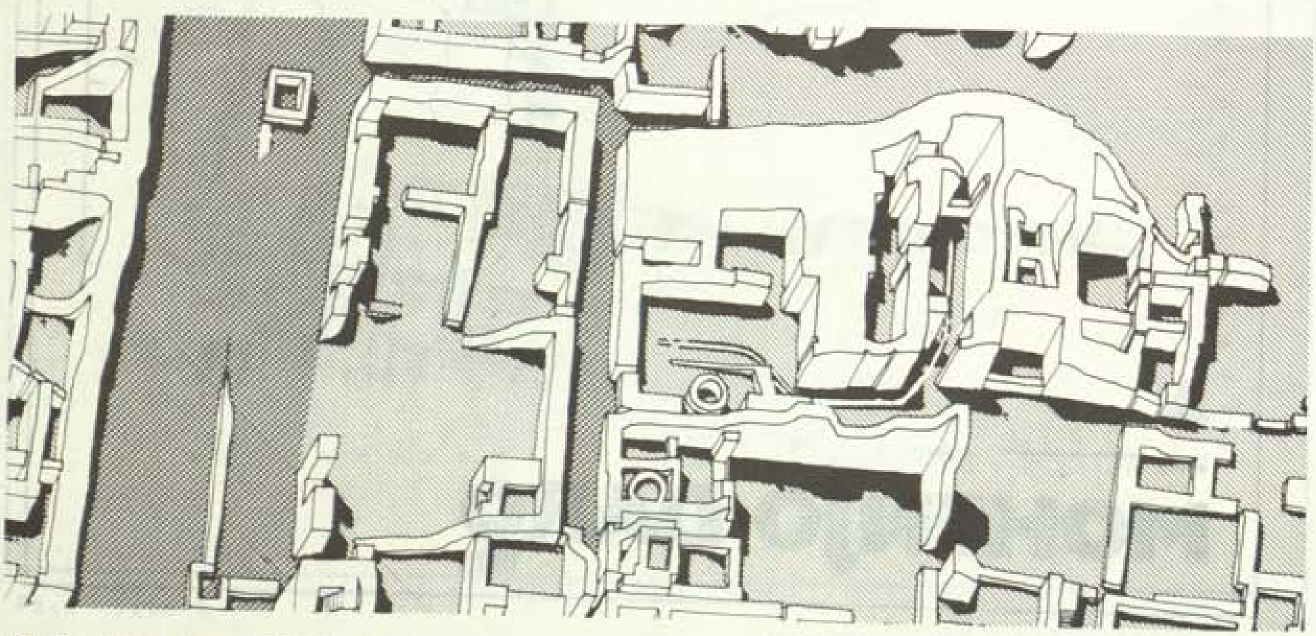
Pl.5 Site 4



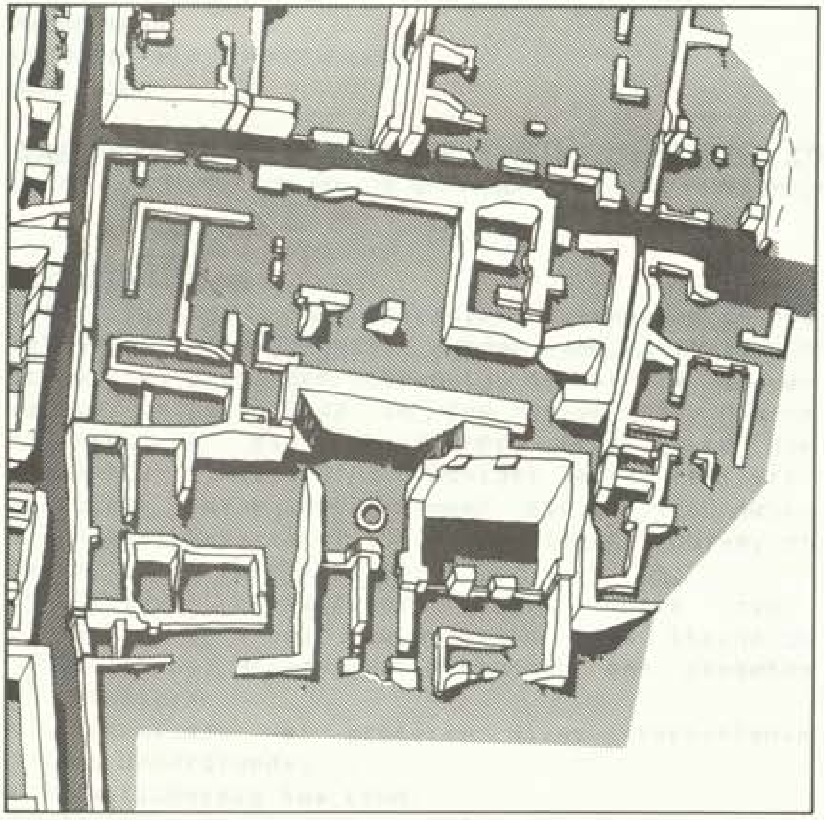
Pl.6 Siteplan of Mohenjo-Daro



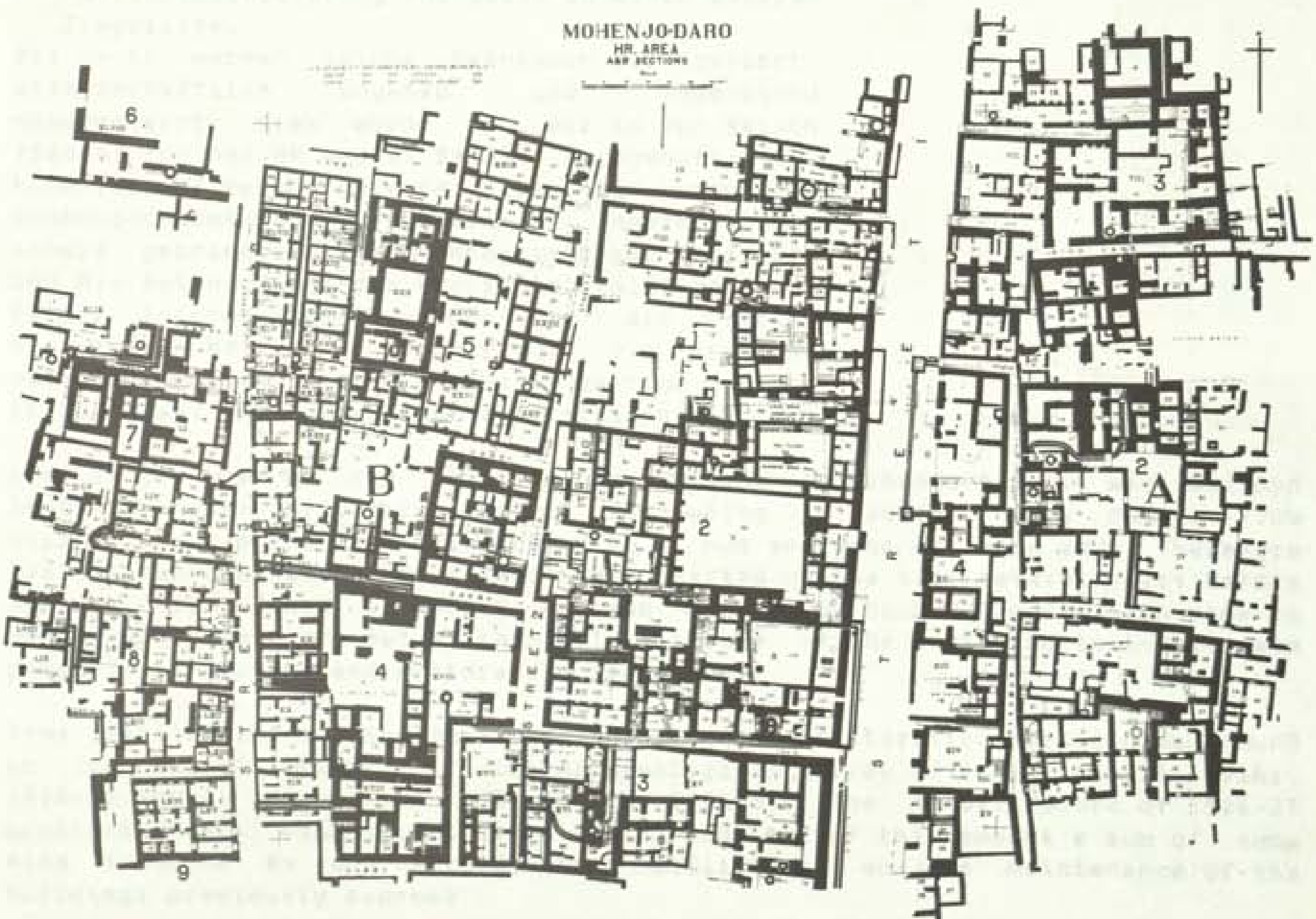
Pl.7 Concept of analyzing the archaeological data of Mohenjo-Daro



Pl.8 Isometry of HR-A area showing a drain joining structures at different heights



Pl.9 Isometry of HR-A House I



Pl.10 HR-area (Marshall 1931, HR pl.XXXIX)

Pl.2 Isometry of HR-A area showing [illegible] at different heights

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SOME PROBLEMS CONCERNING THE EVALUATION OF WALL STRUCTURES IN MOHENJO-DARO

EINIGE ANMERKUNGEN ZUR ANALYSE DER MAUER-STRUKTUREN IN MOHENJO-DARO

ZUSAMMENFASSUNG

Restaurierungs- und Restaurationsarbeiten an den Bauwerken Mohenjo-Daros wurden unmittelbar nach den ersten Grabungen notwendig, da das im Grundwasser gelöste Salz in den freigelegten Mauern massiert an die Oberfläche tritt und die gebrannten Ziegeln binnen weniger Jahre zerstört. Spärliche Informationen über die Arbeiten geben die Annual Reports of the Archaeological Survey of India, Dehli seit 1926/27:

- Austausch zerstörter Ziegel durch neu angefertigte oder aufgelesene alte Steine in Teilen der Mauern oder Neuaufbau von gesamten Strukturen.
- Stützmauern bei größeren Niveauunterschieden des Untergrunds.
- Schutzüberzug aus Lehm.
- Horizontalisolierung aus Beton in einer unteren Ziegellage.

Bis heute wurden solche Maßnahmen durchgeführt, wissenschaftlich ungenau und ungenügend dokumentiert; dies wurde von mir in der Saison 1980/81 für den HR und VS Bereich nachgeholt. Hinweise auf rekonstruierte Strukturen geben alte Grabungsphotos und -grundrisse, neuzeitliche, scharf gebrannte Ziegel, unregelmäßiges Mauerwerk und die Betonschicht der Horizontalisolierung. Diese Informationen wurden in die 1:200er Grundrisse übertragen, wobei auch die Bereiche markiert wurden, über die eine eindeutige Aussage in Bezug auf ihr Alter nicht zu erstellen ist.

Even at the time of the earliest excavations in Mohenjo-Daro it was realised that the exposed brick architecture was going to suffer heavy damage from salination once the protective covering of mud and sand was worn away. Therefore restoration operations had already been started on the site several years before January 1964, when a UNESCO mission headed by Dr.H.J.Plenderleith came to Mohenjo-Daro to carry out a chemical analysis of the salts and to investigate possible protective and restorative techniques.

Some detailed information regarding the extent of restoration work can be found in the Annual Reports of the Archaeological Survey of India (ARASI), Delhi, 1926-27 and in those from 1930-34 to 1936-37. The Annual Report of 1926-27 mentions a total expenditure of Rs 60,152 and "out of this amount a sum of some nine thousand Rs had already been utilized... on the maintenance of the buildings previously exposed".

A more differentiated source is the Annual Report of 1934-35:

A sum of Rs 517 provided under the heading Exploration was also utilized in repairing the monastery at the Stupa Site at Mohenjo-Daro... The walls of monastic cells have been restored to different heights so as to show their outer as well as cross walls, which, having perished down to the floor level, could hardly be traced before conservation.
(Pls.1, 2).

The measures taken were not limited to reconstructions but also comprised retaining walls to buttress particularly high excavated walls, e.g. in DK-G area, First Street (Pl.3) and in the VS area, where retaining walls were also erected to avoid the slipping of upper, unexcavated strata down onto lower levels (Pl.4).

The restoration operation continued during 1930-34:
In a brief note submitted by Mr. E.J.H.Mackay, Special Officer for Exploration, mention is made of the fact that the mud mortar used by the ancient inhabitants of Moenjo Daro amply served its purpose as long as it was free from salt; but now that the buildings are exposed to the air, the salt is having its way, and the mortar is ceasing to serve its purpose. Consequently, two masons and six labourers have been at work during 1930-31 repairing the masonry and resetting where necessary.
Even at that time a further destructive factor did not escape notice: "Visitors to the site cannot avoid walking along the walls and some damage has been done here and there unintentionally, and this will happen in the future, too". He is certainly right in his remarks; visitors can still cause problems today as there is no fence around the site which is traversed by the road from Dokri to the Indus and the nearby villages. A hundred camels peacefully trotting through the remains can be a very impressive sight, but one can imagine the joy of desperate archaeologists engaged in surface analysis.

Besides other repairs the Annual Report of 1935-36 mentions: "covering, as an experimental measure, the tops of conserved walls of the Buddhist Monastery round the Stupa with two courses of sundried brick in order to minimize the destructive effect of saltpetre, which is an ever present danger...". This happens to be a method which is still in use today, though unfortunately restricted to only a few areas of the excavated site. The salt dissolved in the humid air and the ground water crystallizes in the mud covering of the walls (the heavy rains during the summer turn the two courses of mud bricks into a dense covering of the whole wall) and therefore does not affect the inner bricks themselves.

Recent preservation work undertaken by the Preservation Authorities at Mohenjo-Daro can be summarized into two main measures, the replacement of damaged bricks by new ones (mostly a few courses but sometimes complete walls) and the installation of a horizontal, concrete insulation layer close to the base of the walls in order to prevent the salt dissolved by humidity from rising up into the bricks and crystallizing on the surface, with the result that they eventually disintegrate.

Pls.5 and 6 show damaged brickwork which will be rebuilt after the removal of a few layers prior to the insertion of a course of bitumen blocks. This course will later be plastered in red and incised with lines to simulate brickwork. Specially manufactured bricks as well as old ones which are still in good shape are used for such restoration work.

This method results in the humidity rising up only as far as this horizontal insulation course, but unfortunately also in a higher concentration of salt below it. In many excavated areas the installation of the horizontal insulation

course proved very effective although this technique urgently needs further development, as the concentration of salt below the insulation course increases the danger of the whole wall collapsing.

In addition, some doubts have been raised concerning the scientific reliability of the reconstructed areas. Instead of being exactly reconstructed, various bricklaying techniques, joinings, blocked passages, gaps etc. visible on the original photographs were often simply indicated, incompletely reconstructed or even ignored in practice.

Exact information concerning the extent and nature of restoration operations must be available to scientists investigating the architecture of Mohenjo-Daro. It sometimes proves very difficult to identify reconstructed parts due to the fact that ancient bricks have been reused for repairs:

Repairs on the excavated monuments have been carried out with ancient bricks collected during the course of excavations, but this source having been exhausted one lac of bricks of the commonest size used in the ancient buildings (11"x5.5"x2.25") was specially manufactured.....

From the start, the exact extent of the restored parts should have been clearly marked in order to make it easier to distinguish between original and restored architecture, but this has only been practised recently and on a very limited scale. Ideally, the year the reconstruction was carried should be incised in the wall concerned, but again this was rarely done.

A scientific survey of the architectural evidence can be made on the following basis:

One of the most reliable documentation methods is to compare the remains as they are today with old photographs taken during the original excavations, of which in our case a large number have unfortunately never been published. Through a combination of the photographic documentation being prepared by our project and the original photographs a complete sequence of views taken during excavation, after conservation and today can be obtained. It is relatively easy to distinguish ancient from recent architecture from a comparison of the state of the remains at the time of excavation with present conditions (Pls.9-12). Besides the fact that the old pictures clearly expose new walls built in the interval which never existed in reality, the sequences also show the rapid advance of disintegration due to rising salts in some areas.

As these examples show, there are whole walls standing today which have not very much in common with the structures entered on the groundplans drawn during excation. These "reconstructions" can be easily detected by comparing extant structures with the plans published in Sir John Marshall's "Moenjo Daro and the Indus Civilisation" (London 1931) and in Ernest Mackay's "Further Excavations at Moenjo Daro (Delhi 1938). However, these plans are also to be treated with caution, as can be seen from the irregularities of scale which emerge when they are enlarged or reduced in size and gaps and parallel walls suddenly merge into one another. In addition, as there are no altitudes marked on these groundplans it is possible that remains still lie below the sand and mud which slowly accumulated during the past fifty years.

It should be mentioned that all the reconstruction operations at Mohenjo-Daro had to be undertaken without the more detailed information concerning the architecture available to us today. Quite apart from this consideration, we only have to look to our own surroundings to discover so-called "restorations". Near the remains of the Roman castle of Eining on the Danube there is a reconstructed watchtower which is not only surrounded by an archaeologically unfounded wooden palisade, but which also lacks the stone superstructure which was commonly part

of such wooden towers; not only that, but this building was erected on the wrong side of the frontier - in the enemy territory of Germania Libera.

But back to Mohenjo-Daro. As noted in the Annual Report for 1936-37:

The exposed walls are gradually being reduced to powder on account of the action of salt except where overburnt bricks were used in the original walls which were the least affected. Gaining by this knowledge, the new bricks were manufactured slightly overburnt in the kiln as these are expected to resist the action of salt more than the average brick... In repairing the buildings ordinary bricks have been replaced by slightly overburnt bricks.

Although walls built of these harder burnt bricks are scattered all over the excavated area and, particularly important, are also to be found in the original remains still extant in the DK-A, B and C areas, the solid appearance of these bricks could be an indication of restored architecture. The best way to distinguish original from restored remains is to examine the evidence of the masonry itself, especially in those areas where heavily damaged walls are situated close to newly built ones (Pl.8).

An absolutely essential preservation measure is the horizontal insulation. As already mentioned, this involves the removal of several layers of bricks leaving larger holes, sometimes unfortunately left open for longer periods due to lack of funds. For this reason, we blocked up many of them again during the past two seasons.

At least 2-4 courses above and below the insulation layer are always rebuilt as well, the opportunity sometimes being taken to rebuild the wall completely. When, therefore, the limits between the rebuilt brickwork on both sides of the insulation layer and the adjoining masonry cannot be traced, the possibility that we are dealing with a whole new wall is very high.

In some cases it is impossible to make an absolute differentiation between the old and the new, and therefore these should be marked. When identified, structures of varying reliability are indicated accordingly on the groundplans and are later highlighted graphically on black and white or coloured plans. These plans clearly differentiate between

- original structures,
- partially restored structures (several layers, horizontal insulation etc.),
- completely restored structures,
- incorrectly restored structures (as can be seen from the groundplans, original excavation photographs etc.),
- untraceable structures (already destroyed, covered in sand or mud).

Possibly those areas documented by original excavation photographs should be marked separately.

This entire information plan could then be used as a basis for the evaluation of the originality and the scientific interpretation of the structural remains in Mohenjo-Daro.

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8. Ibidem 21f.

Revised by Dr.M.Mulloy

Fig.1 Monastic cells before conservation

Fig.2 Monastic cells after conservation 1936

Fig.3 DK-G, First Street showing retaining walls

Fig.4 VS-A, Southern Part, showing modern retaining walls

Fig.5 MN area, showing holes in the walls for the installation of horizontal isolation

Fig.6 VS-A area, showing installed and plastered horizontal isolation

Fig.7 HR-B area, showing restored wall with incised date of reconstruction

Fig.8 VS-A area, showing original structures surrounded by restored architecture

Fig.9 VS-A area, showing excavations 1926

Fig.10 Same view as Fig.9 today

Fig.11 HR-A area, showing house VIII with well 1926/27

Fig.12 Same view as Fig.11 today

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*AN APPROACH TOWARDS THE REPLACEMENT OF ARTIFACTS INTO THE ARCHITECTURAL CONTEXT OF THE GREAT BATH IN MOHENJO-DARO**

REPLAZIERUNG DES AUFGEZEICHNETEN INVENTARS DER GRABUNGEN DER 20IGER JAHRE

ZUSAMMENFASSUNG

Aufgrund der Wiederentdeckung der Grabungsinventare der Jahre 1924-1937 in Mohenjo-Daro kann jetzt der Versuch einer Rekonstruktion der Ausgrabung des Großen Bades in Mohenjo-Daro unternommen werden, um dann an einem ausgewählten Beispiel die Möglichkeiten einer Neubearbeitung dieser Primärquellen zu untersuchen, d.h. genauer: mit Hilfe der Neubearbeitung aller zugänglichen Primärquellen (z.B. Grabungsinventare, alte Fotos der Grabungsarbeiten und Originalpläne) wird versucht, neues Licht auf Form und Funktion des Großen Bades zu werfen, wobei die Problematik der in den Grabungsinventaren enthaltenen Information stets im Auge zu behalten ist.
Durch die Auswertung der Artefakte und die Strukturanalyse der verschiedenen Bebauungsphasen ergibt sich ein wechselhaftes Bild der Funktion dieser Architektur im Laufe ihrer harappazeitlichen Besiedlung. So spricht vieles dafür, daß das Große Bad als architektonische und funktionale Einheit schon zu Zeiten aufgegeben oder vernachlässigt worden ist, als die Stadt noch von "Harappanern" bewohnt wurde.

In 1979 Michael Jansen, one of the co-authors, came across the unpublished field registers of the excavations carried out in the twenties in Mohenjo-Daro in the library attached to the site museum. Three years later, the Director Archaeology and Museums of Pakistan, M.Ishtiaq Khan, generously granted permission to copy these invaluable documents to the German Research Project Mohenjo-Daro, thus opening the way for a scientific study of a vast corpus of unique data.

Work is already in progress on a computer translation of this material giving details of coordinates, altitudes etc. in the revised coordinate system which we introduced when we started our research in situ. When complete, the decoding and systematic reorganisation of the information now variously preserved, while not providing us with the ultimate answers to all our questions, will definitely provide a sound basis for a critical reappraisal of the entire archaeological

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* With kind permission of Prof.Durrani, Peshawar. Originally published in: Proceedings of the 1st International Conference of Archaeology in Pakistan, March 1982

puzzle of Mohenjo-Daro./1/

Meanwhile, this preliminary report on the present results of the analysis confirms our expectations at the time of the discovery of the field registers. The publication of the final report will naturally be delayed until the completion of the computer programme.

Every previous attempt to analyse the distribution of the material culture of Mohenjo-Daro in its threedimensional context was doomed to failure for the following reasons:

1. The finds published in Marshall's excavation report (1931) are assigned relative vertical locations "below surface" without any indication of absolute depth. On the other hand, Mackay gave the absolute location of the finds he published in 1938 as "below datum". However, as he constructed his chronological sequence on the basis of the relation of his finds to the absolute altitude of their finding-places rather than on a stratigraphic analysis, both his chronology and his method of indicating vertical location "below datum" were denounced by his critics (Wheeler 1954 et al.).
2. Absolute coordinates are also largely lacking from the indications of horizontal location in the published reports of Marshall and Mackay - they content themselves with an Area/Block/House/Room system or relate objects found on the streets to the nearest architectural structures.
3. The absence of a complete list of finds made to date on the site precluded any qualitative-quantitative analysis on their distribution.

Apart from these serious obstacles, the fact remains that the published reports themselves constitute a selective view of the evidence and thus should never have been used as only primary source material on which to base a critical re-approach towards the Mohenjo-Daro assemblage. It comes as no surprise, therefore, that a comparison of these reports with the original body of documentary material - photographs, unpublished reports and the field registers - reveals major differences. Of all the original material the rediscovered field registers contain information of the greatest importance which will provide food for a broad new field of research:

- identity number - all the items registered are numbered in sequence according to the areas in which they were found (e.g. DK, HR, VS etc.). The objects in the care of the museums are mostly inscribed with their respective ID numbers, thus allowing a cross-check with entries in the registers to be made;
- date of excavation;
- horizontal orientation system;
- vertical orientation system;
- brief description.

/1/ Before going on to describe the implications of the newly discovered field registers we would like to express our deep gratitude to those who supported our work, especially to M.Ishtiaq Khan, Karachi, Director Archaeology and Museums, and Miss Salma Sultana, former Curator, and her staff at the Mohenjo-Daro Museum for their kind cooperation. We also want to thank Prof.M.Tosi, Rome, who gave freely of his time and experience in extensive discussions on the computerisation and interpretation of the data during his recent stay in Aachen 1982. A special word of thanks also to our photographers who photographed the registers and to the ground staff in Aachen responsible for the computerisation of the data. Finally, we are deeply grateful to the Deutsche Forschungsgemeinschaft for its continuing financial support.

The field books contain approx. 38,000 numbered entries, and thus roughly eight times more information than the published reports.
Altogether 21 areas and subsidiary areas were excavated.(Pl.1) While the early excavations of Sites 1, 2 and 3 by Banerji (1922-23) and Site 4 by Vats (1923-24) are not represented in the registers available, their plans and photographs are well preserved.

The systematic entries in the registers commence in the year 1924 and are mainly a record of the archaeological activities of Mr.Dikshit (DK-area), who was later to become Director General (1937-44) of the Archaeological Survey of India. Dikshit must have had a complete provisional site plan of Mohenjo-Daro at his disposal which allowed him to introduce an orthogonal orientation system in feet on N-S/E-W axes using point coordinates (e.g.150x820) for his 1924-25 excavations. This network of horizontal point coordinates (PC) was incorporated not only in the DK A, B, C, D, D' and E' areas in the so-called 'lower town' but also in sites F and SD on the 'citadel'.

The trial trenches dug in 1924-25 are scattered all over the site.(Pl.2) As the same horizontal point coordinates system is used to refer to them in the registers, it is clear that a detailed geodetic net must have already been worked out. A comparison with the new metric net introduced by the German Research Project uncovered only minor deviations, arising from the differing orientation towards magnetic as opposed to astronomic north.
With the appearance of Marshall 1925-26 (Pl.1) Dikshit's orientation system changes from point to area coordinates (AC-system). The indications of horizontal location in the field book entries are based henceforth on a 100' grid subdivided into twenty-five 20' units. The successive 100' grids are labelled alphabetically from E to W and numerically from N to S whereas the subdivisions are numbered from 1 to 25. Thus the 100' grid coordinates 24l1 are located in the centre of the 'Great Bath', in the tank.
This AC-system is shown on most of the maps published by Marshall (1931) and Mackay (1938). Although Marshall probably changed the nomenclature from PC to AC for reasons of rationalisation, the fact remains that for the purpose of modern analysis Dikshit's PC-system is more practicable as the area coordinates referring to 20'x20' units are too inexact.
Dr.Mackay , whom Marshall appointed as his successor on the excavation at Mohenjo-Daro, introduced a third horizontal orientation system when he started work in the L-area. Rejecting the overall grid system, he preferred to indicate each individual location by relating it to the relevant architectural units. Wherever he believed he could identify compartments, he numbered them in sequence. In his publication of 1938, he gave practical difficulties as the reason for the change of orientation system (ibid. XIII):

> Before excavation the ground was pegged out in squares of 100 ft. and it was from the nodal points that the buildings were planned. These points were remarked as required at lower and lower levels with the help of a theodolite. We soon found, however, that we could not use these squares, even if subdivided, for the identification of either of the findspots of the objects unearthed or of the position of the rooms; for frequently we found ourselves working in rooms with high walls on all sides, so that it would have required a very elaborate and time wasting process to correlate the postion of our finds with the squares. Accordingly we adopted the system of numbering rooms and walls.

Mackay's relative system (R-system) was adopted by Raj Bahadur Daya Ram Sahni in the HR-B and VS-B areas in the 1926-27 season. Although it had the advantage of allowing finds to be correlated directly to the structural remains, the disadvantage of the system was that it could only be applied with the help of a plan showing the room numbering.

To complete the confusion, none of these horizontal orientation systems is incorporated in the final publication; here a fourth system is introduced, whereby each Area, Sub-area, Block, House and Compartment receives its identification tag (e.g. DK-G north 1 II 15). At the same time this published system, which was not used in the field books, represents the final structural interpretation of the architectural remains.

Whereas the first two orientation systems described above can easily be reconstructed, Mackay's relative system can only be deduced from a comparison of the field book and the published systems, as the ID-number is the only information incorporated unchanged in both. However, as not all ID-numbers are published, the room numbering system has to be completed mathematically. There is still hope that Mackay's field plans showing the original room numbering will turn up. The disadvantages of this room numbering system have already been demonstrated for the DK-J or Moneer Site (cf. Jansen in Wheeler Memorial Volume, Delhi, unpublished). Its excavators, Moneer (1933-34) and Puri (1936-37), both used the same room numbering system. Unfortunately, as none of their excavation plans has since turned up, about 1,100 registered finds cannot be related to their proper architectural contexts.

Only two vertical orientation systems, a relative depth system "below surface" and Mackay's absolute depth system "below datum", were used in the field books and taken over unchanged in the published records. Mackay's vertical system can be used to relocate the finds threedimensionally. In this respect his system, which came in for heavy criticism by Wheeler et al., turns out to be very fruitful for current research. Although his stratigraphic interpretation based on absolute depths is incorrect, the absolute reference system itself could conveniently be used in an analysis of the distribution of find clusters at various depths which, when correlated to the relevant architectural context, may contribute towards a revised relative chronology of the settlement. This problem will be discussed in greater detail below.
Before such an analysis can be carried out, all relative depths "below surface" have to be given absolute values. Only then will it be possible to correlate the excavated objects with the structural remains cleared by the German Research Project.

The pre-excavation topography of the site can be reconstructed with the help of the following primary source material:
1) the unpublished topographic map of the site before excavation, recently rediscovered by the authors (Francis plan);
2) photographs of partly excavated structures complemented by the results of our levelling operation,
3) the levelling of all wall tops and, finally,
4) recorded information.

With the reconstruction of the horizontal and vertical orientation systems and the resultant relocation of the finding places of the objects registered in the field books, the real work of analysing the entries scientifically and interpreting the stratigraphic distribution patterns of find clusters can commence.

THE GREAT BATH: ARCHITECTURAL FEATURES AND ASSOCIATED FINDS (PL.3 AND 4)

The Great Bath has been selected for closer analysis because it is not only one of the most prominent structures in Mohenjo-Daro but also because it has attracted most critical attention. This is evidenced by the fact that it has been largely rebuilt (about 80%; Pl.5), and occasionally the opinion is even to be

heard that the Great Bath does not fit into the familiar Harappan pattern and possibly might not be Harappan at all.

The complex was excavated in 1925-26 by Sir John Marshall and Mr.Siddiqui (after whom the northern, SD-area of the citadel is named). Marshall's first report of their work in the tank section appeared in ARASI (1925-26) p.72 ff.:

Simultaneously with the sinking of the deep trial trenches described above, an area of some 9,000 square yards was excavated to the south-west of the Stupa mound and a complex of buildings brought to light, more imposing than any yet found on the site.

... Most striking among the buildings discovered is the massive structure designated the "Bath", which lies parallel with the west side of the stupa court and about 100 feet from it.

One of the largest structures in the SD complex, the Great Bath measures 52m N-Sx32,4m E-W, covering an area approx. 1685sqm (Pl.6) in extent and thus roughly comparable in size and proportions to the 'Granary' west of it (54m E-Wx34m N-S, 1836sqm).

There is a third structure of similar dimensions, Block 18 in the DK-G north area, 54m N-Sx34 E-W, 1836sqm.(Pl.7) The foundations of this structure would appear to indicate another unique piece of architecture in the MD context.

These three are the only large structures which are rectangular - the 'Granary' only being rectangular in its original form without later additions in the SE. Incidentally, their proportions (Great Bath - 0.62, 'Granary' and Block 18 - 0.63 each) are reminiscent of the Golden Mean (0.618), though naturally there is no evidence of any consciously planned proportional concept.

Still the best guide to the layout of the Great Bath, Marshall's plan (Marshall 1931; Pl.XXII) shows both the original and the reconstructed portions.(Pl.6) As becomes immediately apparent from the plan, there are no adjoining structures and it would appear to have been surrounded on all four sides by streets or passageways. The western passage was subsequently narrowed by Block 6 of the neighbouring 'Granary' and eventually blocked completely.(Pl.8) The northern passage was also narrowed at a later date.

That the western passage formed part of the original circumambulatory can be seen from the fact that it was on the same level as the other passages, clearly indicated by the top of the extant drain leading northwards from the tank before turning west after a few metres across the NE edge of the lower part of the 'Granary'.
It follows also that the lower part of the 'Granary' is older than the Great Bath and that at least the eastern portion of it was below ground level when the Great Bath was in use. It may be concluded that only the upper part of the 'Granary' represented by the surviving passages and blocks may have been contemporary with the Great Bath. This, too, would indicate that the upper part of the 'Granary' had no direct functional connection with the earlier 'loading platform' as Wheeler suggested.(Pl.9) Further analysis of the 'Granary' is currently underway as Wheeler's original plans have been located.

STRUCTURAL ANALYSIS

In its present state the 'Great Bath' is a conjectural reconstruction according to Marshall's plan (1931; Pl.VII), and therefore represents a subjective interpretation not always backed up by archaeological evidence. In the following, an attempt will be made to reinterpret the structural remains as they appear on the original groundplan and photographs.

As the original plan shows, the structure consists of five concentric rectangles of which the innermost one forms the tank itself. Originally, a circumambulatory around the entire structure formed a sixth rectangle.(Pl.8)
All the rectangles except the fifth comprise two symmetrical halves divided by the N-S axis represented by the two flights of steps leading into the tank. The fifth rectangle is incomplete - on the W it runs into the western side of rectangle four. Only thus could the circumambulatory be continued on this side, where space was restricted by the older 'Granary' structure.

Investigation showed that the central tank was completed after rectangles 2 and 3, which were constructed contemporaneously. Rectangle 2 either represents an earlier, larger tank inside which the present central tank was built, or it was no more than a functional support erected to ease the construction of the elaborate central tank./1/ Concerning rectangle 2, Marshall remarks (1931: 136):
Consolidated as all these walls are with mud filling, they would seem to have supported an ambulatory around the bath of the width of 15 feet or so ... It is possible, of course, that the middle one of the three walls surrounding the bath also had a series of apertures, though no trace now remains of them.
Marshall's suggestion that a second row of pillars once existed may perhaps be borne out by the presence of the two retaining walls in the S and the four in the N, again symmetric in relation to the dividing N-S axis, and by the five (six?) retaining walls in the E. This would mean that the only access to the central tank would have been via the flight of steps, as the distance between it and the surrounding inner pillars would have been too narrow for an approach. The four brick piers (28-31) may have served as pillar supports.
On the other hand, it has been suggested that these piers may have been intended to support some ornamental features, such as columns or statues. (Marshall 1931: 135)

As direct structural evidence is lacking, however, such suggestions are no more than speculation. Regarding the third rectangle Marshall writes (1931: 136):
The outermost of the three walls surrounding the bath supports a fenestrated wall overlooking this portion. Assuming that the apertures in this wall on the eastern sides were of the same size as those on the north and south, as seems probable in view of the preservation of the two that still remain at the southern end of the western wall, there would have been nine on either side.
(Ten according to the plan)

Although only a few of the hypothetical 20 original pillars making up the eastern and western rows have been traced in situ, Marshall's proposed reconstruction appears highly probable. Worthy of note is the fact that the interspaces had high sills (0.5m approx.), which prompted Marshall to call them "windows". His argument that the sills are later additions is unacceptable as originally they would have been 1'2" below the contemporary pavement (ibid.: 136, footnote). In that form the interspaces could not have served as direct access routes to the central tank.
While searching the records for a reference to an entrance, we came across a remark concurring with the plan, a cross-section drawing and a photo.(Pl.10) Marshall writes (ibid.: 135):
The upper parts of these walls (rectangle 3) are preserved to a certain height at the northern and southern ends, both ends being provided with six apertures. These apertures, except one which was used as a doorway, were at a later date partially filled in and served as windows.
This entrance would have provided direct access from the S to the southern staircase on the N-S axis.

/1/ The second explanation seems to be more realistic.

The circumambulatory provided mere visual contact with the central area through the fenestrated wall, whereas access to it was only possible from the S. Two entrances in rectangle 4, representing the outer limit of the circumambulatory, likewise opened on to it from the S. A single row of chambers bordering the eastern side of the circumambulatory can all - with the exception of room 20 - be entered from it.
The outer limit of the entire complex is represented by rectangle 5, a wall more than 2m thick. As in the case of rectangle 4, a double entrance system comprising two openings leads through rectangle 5, likewise from the S.(Pl.8) This form of double access recurs in HR-A, Block 1, a large structure also entered from the S with a pair of staircases leading up from the doorways to a northern section more than 2m above the lower part.
Besides the openings in the S, there was a further one in the northern side of the outside wall of the Great Bath which was later blocked up. Two large jars were reported to have been found here in association with a well paved floor surrounded by a brick wainscot. Marshall termed these jars "funerary vessels" (ibid.: 137, note 5), which, as our investigations have shown, seem to be more likely containers used in connection with bathing platforms.(Pl.11)

Apart from the 'ring system' of concentric rectangles, there is a 'transparent' zone in the northern part of the structure formed by three rows of pillars which once supported the roof of a hall measuring approx. 22m E-Wx15m N-S and covering an area approx. 330sqm in extent. As the central axis of the tank is not continued northwards in the form of an access route to the pillared hall, the latter was presumably entered from the circumamblatory. So far no direct information on the function of this hall could be obtained from associated finds.

The archaeological evidence shows that the function of the Great Bath changed in later times. The various stages of structural alteration can no longer be reconstructed, but at least the final form of the building before it was abandoned can be determined.(Pl.12) The most radical alteration was carried out in the northern part of the complex where a staircase leading to an upper storey or to the roof was built in passage 21, thereby blocking off the doorways to rooms 20 and 24. It is uncertain whether the entrances to rooms 14, 17 and 18 were blocked up at the same time.

Later still, the circumambulatory around the tank was intersected at intervals by doorways and the northern pillared hall was partly blocked up resulting in several smaller compartments.(Pl.13) All entrances to the tank except the southern one were sealed. The accesses from the S to the ambulatory were reduced to one. In general, the ingenious layout was transformed into a cluster of micro-units, indicating a clear change in function. The external circumambulatory was also interrupted through secondary blocking in the SW and N.

A roughly built drain traversing the south-eastern entrance through the external rectangle 5 about 2.5m above pavement level indicates very late functional activity long after the Bath complex was abandoned.(Pl.14)

RELOCATION AND ANALYSIS OF FINDING-PLACES OF OBJECTS RECORDED IN EXCAVATORS' FIELDBOOKS

The only way possible to relocate the finding-places of objects unearthed in the Great Bath was to reconstruct the original coordinates. This was done with the

help of the few objects published by Marshall in 1931 (App.I), whose coordinates were distributed in sufficient number over the area to allow the approximate grid to be worked out.(Pl.15)
Later we discovered a provisional plan of the Great Bath showing the excavation grid omitted from the later published plan.

Trench F, south-east of the Great Bath, provided the information required to reconstruct the point coordinates and thus also to correlate the two systems, e.g. coordinate 24 = 1680', 11 = 3140'. The numerical sequence runs at 100' intervals from N to S (25 = 1780') and E to W (mm = 3240'). The reconstruction showed that the 100' grids are named after the position of their SW corners and the 20' sub-squares numbered in vertical columns beginning with square 1 in the NE corner and ending with 25 in the SW (Ardeleanu 1981).

Once a horizontal orientation system for the Great Bath was made available in the form of the reconstructed grid, work could commence on correlating the ID-numbers of the relevant finds in the registers with the grid coordinates. Of the 725 ID-numbers isolated from the registers 40 had to be disregarded due to inadequate description, leaving a total of 685 for statistical analysis (App. II).

ANALYSIS OF THE REGISTERS

Generally, six data are recorded for each register entry:
- consecutive field number
- date of excavation
- square and subsquare as horizontal orientation
- level as vertical orientation
- short description
- if on loan to another museum the relevant key number was entered at a later date.

These six data can be divided into two classes, the one formal and objective, the other descriptive and subjective. The non-descriptive information regarding number, date, orientation and key number can be considered objective as it is fixed and verifiable.
The descriptions, on the other hand, must be considered subjective as they are based on non-standard criteria and were formulated by several different excavators./1/
These criteria concern - at the most - six specifications of varying reliability:

- number	- condition
- size	- form
- material	- function

As it is not possible at present to check the descriptions by comparing them to the relevant objects, the data can only be analysed and interpreted on a general level in view of the vague and subjective nature of the information available.

ANALYSIS OF THE OBJECTS

Before an iterative evaluation of the data can be attempted, the material under analysis has to be classified along clear-cut lines.

/1/ The descriptive criteria were standardised by Mackay in 1927.

It must be borne in mind, however, that due to the descriptive nature of the information gathered to date its classification must be subject to certain restrictive conditions. But once laid down, these conditions represent a useful set of basic criteria according to which the register entries can be evaluated.

As a guideline we availed of the object classification system already devised for the Mundigak material by Jarrige/Tosi (1979: 127f.)/1/:

subsistence	- food, fuel, clothing/dress, shelter;
instruments	- wasters, tools/weapons, vessels/containers, building materials, paints/dies, glues, raw materials;
administration	- seals, sealings, counters, tools for control and registration of economical transactions;
prestige and ideology	- figurines, sculptures, beads/pendants, bangles/rings, inlay work, objects of no direct economic purpose.

As already expressed by the authors cited (1979: 128), this classification according to function is still fairly broad and further specific refinements must await more detailed study. Therefore our adoption of this preliminary system must not be taken as definitive, but rather as a working model whose results can only be adjudged in relation to the prevailing conditions.

THE RELOCATION OF THE OBJECT FINDING-PLACES

In order to study the threedimensional distribution of finds in their architectural context an ideal programme was worked out.(Pl.17)
Due to the inadequate state of our information on the objects, however, this ideal programme cannot yet be attempted. In the meantime, we have resorted to a provisional study programme based on the data available at present.

HORIZONTAL AND VERTICAL DISTRIBUTION OF THE OBJECTS

The horizontal distribution can be analysed on the basis of either the grid system in use - thus obtaining an impression of the general spatial distribution - or the architectural context, which would allow conclusions on the functional aspect to be drawn.
The second method brings us up again the problem that the grids do not necessarily correspond to architectural units, as the compartments, houses and blocks were only numbered consecutively from 1927 onwards. The correlation of the grid system and the architecture is shown in App.III, which differentiates between grid squares that are identical in area to architectural units (I) and those not identical (NI), i.e. where structures overlap into neighbouring squares. A computer analysis currently in progress will supply us with the synchronic percentage distributions of objects necessary for the optimum evaluation of the correlation.

As regards vertical orientation, the level of the finding-places of objects unearthed before 1927 is recorded only in feet below surface. Although in the final published reports the architectural measurements are given in relation to

/1/ We have made the following slight alterations to this system: unidentified objects are excluded from the instruments class while raw materials are added to it. Inlay work is included under prestige and ideology. As yet, the wasters group of objects bears no relevance to our investigation.

a datum level /1/, it was only possible to work out the absolute level of a find in a single case /2/ reported to have been located on the pavement of passage 3 at a depth of 10' (= 52.96m above MSL.).

The basic sources for the reconstruction of the topography before excavation were:
- our levelling of the surface and the present state of the architecture;
- the old photographs taken during the excavation;
- the records of finds which give their location in relation to structural features such as pavements, staircases etc.

By means of an iterative approximation the absolute levels of the subsquares were reconstructed as shown. (Pl.16 and App.II) The comparison of our levelling of the Great Bath with Marshall's (1931: 135) showed a mean deviation of 1.7m approx., while the comparison of our MSL. data with other datum levels in Mohenjo-Daro proved ours correct./3/

To ease the analysis of the objects recorded as having been found in the Great Bath area, this structure was broken down into five units. The following table gives the percentage distribution of the total of 685 finds among these five structural components:

1. Inner courtyard, bounded by fenestrated wall (rect.3) (including circumambulatory between rects. 3 and 4)	41.46%
2. Eastern row of compartments/4/	29.78%
3. Southern entrance room	11.82%
4. Tank	8.18%
5. Northern hall	7.30%

The tank itself is covered by only two complete subsquares, 251121 and 241125, and parts of 25mm1 and 24mm5. As it is not yet possible to evaluate the distribution of finds in the latter pair they are omitted from this analysis.

According to the registers, there is a concentration of objects 8' below the surface, i.e. on the original floor level of the tank (50.60m above MSL):

Objects found 8' (50.60.m above MSL) below surface (251121):

SD 1959 min2	shell objects
1960	three globular beads
1962	steatite seal with pictographs/5/
1963 min2	faience beads (at foot of staircase);
1964	piece of silver
1965 min2	copper objects
1966 min2	bone pieces
1967	fragment of bangle
1968	scraper
1969	stone piece (rectangular), (2nd pavement below staircase)
1970	round stone
1971	conch shell
1972	3 t.c. toys
1974	white stone

/1/ The top of the well in R16 (Marshall 1931: 135)= 168.1' = 51.23m above MSL

/2/ Bull figurine SD 2184 (Marshall 1931: 138);Pl.18b

/3/ Therefore it must be assumed that the bench mark on the well in R16 is too high by 1.7m.

/4/ The largest amount of objects was found in R13 - 63 (9.19%) - and in R14 - 44 (6.42%)

/5/ This seal, the only one found in the tank, is not mentioned in Marshall's official excavation report, but is included as No.458 in his list of seals (Marshall 1931: 405, Pl.CXII, 458) and published in ARASI 1925-6, Pl.XLV and in Koskenniemi/Parpola (1973: 41, No.145823099); cf. Pl.18c. It is stored in the Lahore Museum where it has been recently identified by A.Ardeleanu

Objects found 8' (50.60m above MSL) below surface (241125):

SD 1999		shell bangle fragment
2000		lump of copper
2052		copper chisel
2054		cube shaped bead

The following objects were found at a depth of 6.5' (51.05m above MSL) close to the foot of the staircase in subsquare 251121:

SD 1526		faience object
1527		circular faience object
1528		three scrapers
1529	min2	copper objects
1530	min2	faience beads
1531		ball
1532		fragment of carnelian bead
1533		tiny black coloured pot
1534		conch
1535	min2	faience objects
1536	min2	fragments of black ware
SD 1598		t.c. animal figurine
SD 1645		t.c. bird

The highest concentration of finds close to the floor of the tank is reported from the southern portion - 84.6%. This may have been caused by the downward slope of the floor towards the S.

Due to the fact that we cannot be sure that the objects were found in their primary positions, any interpretation of the threedimensional distribution must start from the following assumptions:

- the objects found closest to the floor or pavement offer the most reliable information about the time when the Bath was still in use;
- the general contents of the tank itself furnish information on the time it ceased to be used, which probably coincided with a functional change of the entire complex;
- the objects close to the surface are the best source of information regarding the later and final use of the area.

We are aware of the dangers inherent in such a simplified chronological approach; nevertheless, we feel sure that the hypothetical disturbances in the operation of the Great Bath can be calculated statistically from a recheck of the finds, including those now scattered in various museums.

HORIZONTAL AND VERTICAL DISTRIBUTION OF OBJECT CLASSES

On the basis of this general approach towards a spatial and stratigraphic distribution in relation to the classification outlined above the following preliminary results were obtained:

1. General percentage distribution of object classes (after Jarrige/Tosi 1979):

1.1	Subsistence	13.28%
1.2	Production	24.10%
1.3	Administration, communication	2.20%
1.4	Prestige, ideology	39.85%
1.5	Unidentified fragments	17.95%
1.6	Others	2.62%
		100.00%

2. Percentage distribution of the same object classes according to:
1. clusters on or close to floor level, or 2. clusters close to surface:

	1) Floor	2) Surface	Difference
Subsistence	10.00%	6.50%	- 3.50%
Production	7.40%	10.00%	+ 2.50%
Administration	1.50%	1.56%	+ 0.06%
Prestige, ideology	34.00%	12.10%	- 21.90%
Unidentified objects (floor and surface)	----- 16.94% -------------------		

As this preliminary classification of finds shows, those assigned to the prestige and ideology class predomiate in the general distribution (39.85%), followed by the production (24.10%) and - if we exclude the unidentified objects (17.95%) - subsistence classes (13.28%), whereas administration and communication is represented by a mere 2.20% of the total.
When differentiated according to find cluster levels the prestige class of objects decreases from 34.00% on the floor level to 12.10% on the surface while the production class increases from 7.40% to 10.00%. The subsistence indicators also decrease towards the surface whereas the administration class remains almost constant.

PRELIMINARY CONCLUSIONS

The structural analysis of the architecture of the Great Bath reveals at least four phases of construction activity:

1) The initial construction with those imposing features which show that it was intended as a representative piece of architecture, e.g. rectangular form, proportion 0.63, enclosing walls about 2m in thickness, concentric layout around the central tank, central axis as the structural backbone of this layout with an additional functional aspect (twin staircases, probable twin entrances from the S), transparency (transit rooms) of about 80% of the structure, signs of circumambulation, prominent situation etc.(Pl.8)
2) Functional alteration as described by Marshall (ibid.: 178), indicated by the blocking up of all entrances but one in the S, raising of floor level in many compartments, bricking up of parts of inner fenestrated wall intersecting inner circumambulatory, blocking up of northern staircase necessitating the sealing off of room 20, building activity in the N and the W resulting in the obliteration of these portions of the outer surrounding streets (outer circumambulatory).(Pl.12)
3) Complete abandonment of primary function probably coincidental with the destruction of the complex. Filling of central tank with debris, removal (destruction?) of eastern and western rows of pillars, partial reuse as production area (cf. ARASI 1925-26: 78).
4) Construction of a drain close to the surface traversing the southeast entrance and ignoring the structure underneath which was already completely buried.

Besides these observations regarding the structural history of the complex, the analysis of the finds revealed that those of the prestige and ideology classes decrease upwards whereas the production class objects increase. As most of the filling seems to be composed of secondary debris which consists - with one reported exception (SD 2685, a Brahmi-inscribed potsherd) (Pl.20) - only of Harappan material, it follows that the Great Bath must have been abandoned as such while the Harappans were still in occupation of the site. This also applies to the 'Granary' west of the Great Bath.

As regards the structural chronology of the 'Granary', it has already been pointed out that at least the eastern and southern portions of its lower part were underground when the Bath was in use, as the line of the drain leading from the latter and the level of the surrounding streets would appear to indicate. The upper part of the 'Granary' may have been in use slightly earlier than and contemporaneously with the Great Bath. Judging by the layout of the drainage system in Main Street W of the Great Bath, this complex was also contemporary with all the neighbouring structures serviced by this drain.

CONCLUDING REMARKS

Even if this analysis of the Great Bath is only a preliminary one it clearly shows the huge potential of information latent in the site data still awaiting analysis. This opens up a new perspective for Mohenjo-Daro research as the work of interpreting the body of data had hitherto been stagnant for fifty years. The detailed work of rechecking the primary source material uncovered by past excavators becomes increasingly important as permission to excavate anew is rare nowadays. This detailed recheck was only made possible by the careful documentation work done by the excavators themselves; although their later critics were by no means reticent, their criticism was directed chiefly at the various interpretations of the data rather than at the data corpus itself. Though all the primary material was available to research in the Mohenjo-Daro museum nobody seems to have used it for more detailed analysis.
In retrospect, it can be safely claimed that even by modern standards the early excavators left a careful record of their findings which is only beginning to receive the critical attention it deserves.

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APPENDIX I

Objects published in Marshall (1931) and the correlation of grid-architecture

	ID-numbers			page
	SD 570	25mm/7	passage west of R8	: 138
	717	25mm/2	western wall of south side of the bath	: 136
	1106	2511/13	s/w corner R13, near doorway	: 139
*	1198	25mm/7	passage west of R8	: 138

* 1231 2511/16 4th cell from the N on the eastern side : 136
1399 2511/16 passage 12 opposite R15 : 139
* 1535 2511/21 debris of tank (foot of staircase) : 133
1759 2511/14 R5 : 138
1781 2511/16 passage 12 opposite R15 : 139
1885 2411/24 clay filling between the 2 northern piers, 28 and 29 : 135
1899 2411/24 filling between the two northern piers, 28 and 29 : 135
1963 2511/21 debris of tank (foot of staircase) : 133
1984 2511/18 passage 11 : 138
* 1998 2411/23 R26 : 140
2052 2411/24 debris of tank : 133
2172 2411/19 northern wall of eastern side : 136
* 2184 2511/19 on pavement of passage 3 : 138
* 2214 2511/11 R15 : 139
* 2375 2511/11 R15 : 139
* 2390 25mm/1 debris of tank : 133
* 2447 2511/11 R15 : 139
2552 2411/16 top of filling northern part staircase 21 : 141
2577 2411/13 R18 : 140

*: SD 2390 and SD 2184 can be seen on Pl.18; SD 2375, 1231, 1535, 1198, 1998, 2214 and 2447 on Pl.21

APPENDIX II

Numerical distribution of artifacts in relation to subgrids

No.	A.H.	O.	No.	A.H.	O.	No.	A.H.	O.	No.	A.H.	O.
2411/6	57.00	1	24mm/1	NR	0	2511/6	55.50	7+	25mm/1	54.50	8
/7	56.5	0	2	NR	0	7	56.00	9+	2	54.50	32
8	56.5	0	3	NR	0	8	56.00	21+	3	54.50	10
9	56.00	0	4	55.00	1	9	56.00	0	4	55.50	21
10	56.00	2	5	54.00	1	10	-----	--	5	-----	--
11	57.00	4	6	NR	-	11	55.00	44	6	54.50	15
12	56.00	20	7	NR	-	12	55.00	17	7	55.00	29
13	56.00	20+	8	NR	-	13	55.00	63	8	55.00	28
14	55.5	2	9	NR	-	14	56.00	20	9	55.50	10
15	55.5	18	10	NR	-	15	-----	--	10	-----	--
16	57.00	21				16	54.5	92			
17	56.00	0				17	54.5	4			
18	56.00	5+				18	55.00	27			
19	55.5	1				19	56.00	13			
20	54.5	9+				20	-----	--			
21	57.00	0				21	53.00	40			
22	56.00	6+				22	54.00	6			
23	55.5	18				23	54.50	14			
24	55.00	22				24	55.50	37			
25	53.00	7				25	-----	--			

Total sum of objects 725
Not representative - 40
685 objects taken into account

A.H.= absolute height
O.= objects

APPENDIX III

Correlation of grid system with architectural structures

Tank:

		Objects
2511/21	I	40
2411/25	I	7
25mm/1	NI	8
24mm/5	NI	1
8.18%		56

Inner courtyard incl.circumamb.:

		Objects
2511/18	NI	27
17	I	4
16	I	92
2411/20	I	9+
19	I	1
24	NI	22
24mm/4	I	1
9	I	--
10	I	--
25mm/6	I	15
7	NI	29
8	NI	28
2	NI	32
3	NI	10
2511/23	NI	14
41.46%		284

Entrance:

		Objects
25mm/9	NI	10
4	NI	21
2511/24	NI	37
19	NI	13
11.82%		81

Northern hall:

		Objects
2411/16	NI	21
17	NI	--
18	NI	5+
21	NI	--
22	I	6+
23	I	18
24mm/1	NI	--
2	I	--
3	I	--
6	NI	--
7	I	--
8	I	--
7.30%		50

Room 5	2511/14	NI	20
13	13	NI	63
14	12	NI	17
15	11	NI	44
16	2411/15	NI	18
17	14	NI	2
18	13	NI	20+
19	12	NI	20
	29.78%		204

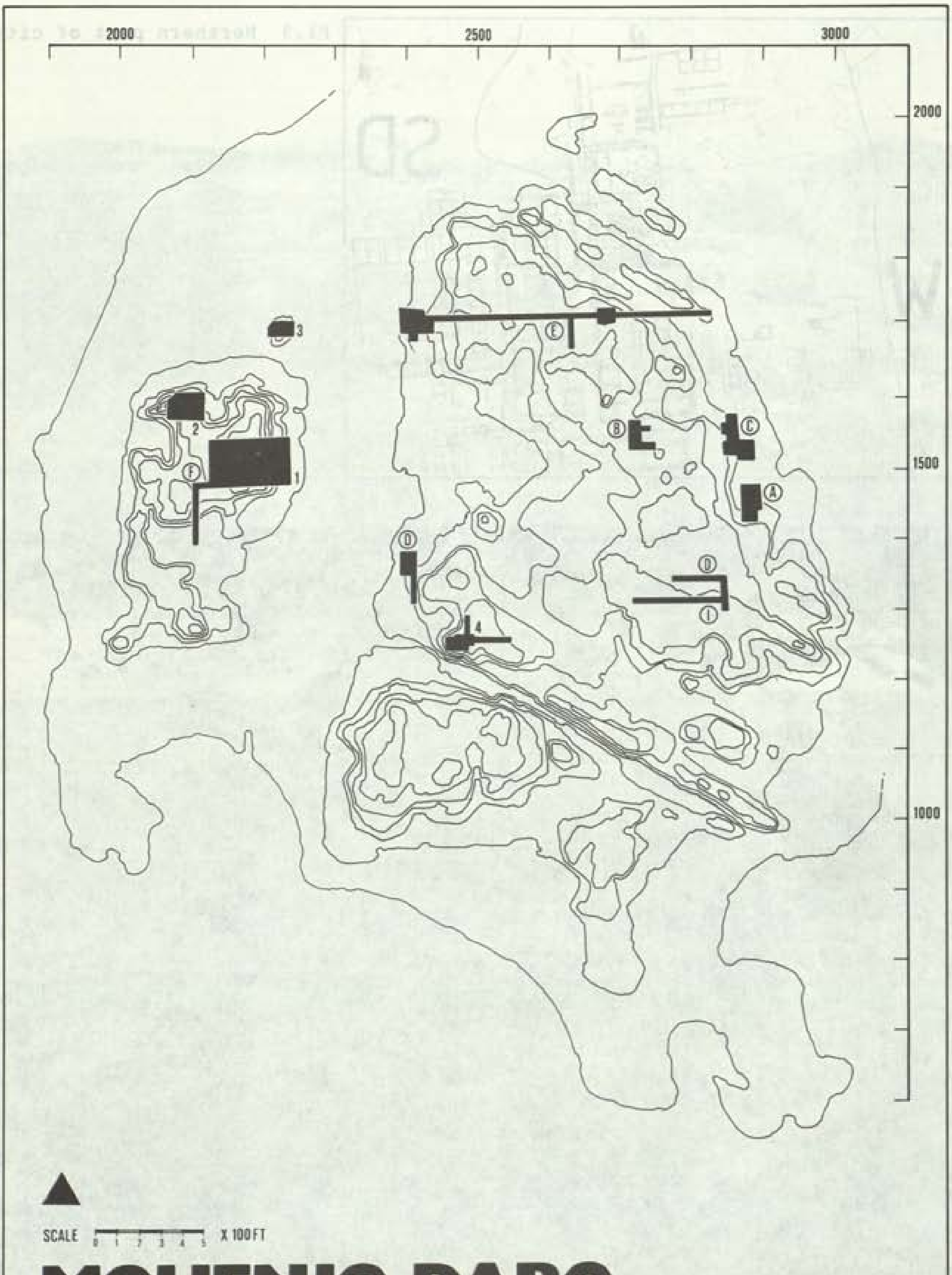
Actual sum of objects:	675	100.00%
Not traceable: 2511/22		
2411/11		1.46%
Total sum of objects:	685	100.00%

1920	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	40	50	64/5	AH	RH	M	R	PH
Site 1		?	?																						XX		XX
Site 2		?	?																						XX		XX
Site 3		?	?																						XX		XX
Site 4			?	?																					XX		XX
DK A				●	●																			XX	XX	XX	XX
DK B				●	●													*						XX	XX	XX	XX
DK C				●	●																			XX	XX	XX	XX
DK D					●																			XX		XX	
DK D′					●																			XX	XX	XX	
DK E					●																			XX		XX	XX
DK F					●																			XX		XX	
DK G							*	*	*	*	*												XX		XX	XX	XX
DK H										?															XX	XX	
DK I												*	*		*	*										XX	XX
VS A					●	O																		XX	XX	XX	XX
VS B						*	*																	XX	XX	XX	XX
HR A					●	O																		XX	XX	XX	XX
HR B						*	*																	XX	XX	XX	XX
SD				●	●		*																	XX	XX	XX	XX
DM					O	O																		XX	XX	XX	XX
L						*	*	*	*														XX		XX	XX	XX
Granary																					??				XX		XX
Fortif.																					??				XX		XX
D																						??	XX		XX	XX	XX

● Feet grid (1200 x 800 / Dikshit)
O 100 feet square grid (24 LL / Marshall)
* Room numbers (Mackay)
? Non identified orientation system

AH = absolute hight
RH = relative hight
M = Maps
R = Registers
PH = Photos

Pl.1 Diagram of excavations showing their time distributions and sources available



Pl.2 First site plan of Mohenjo-Daro published in ARASI 1924-25, Pl.XVI

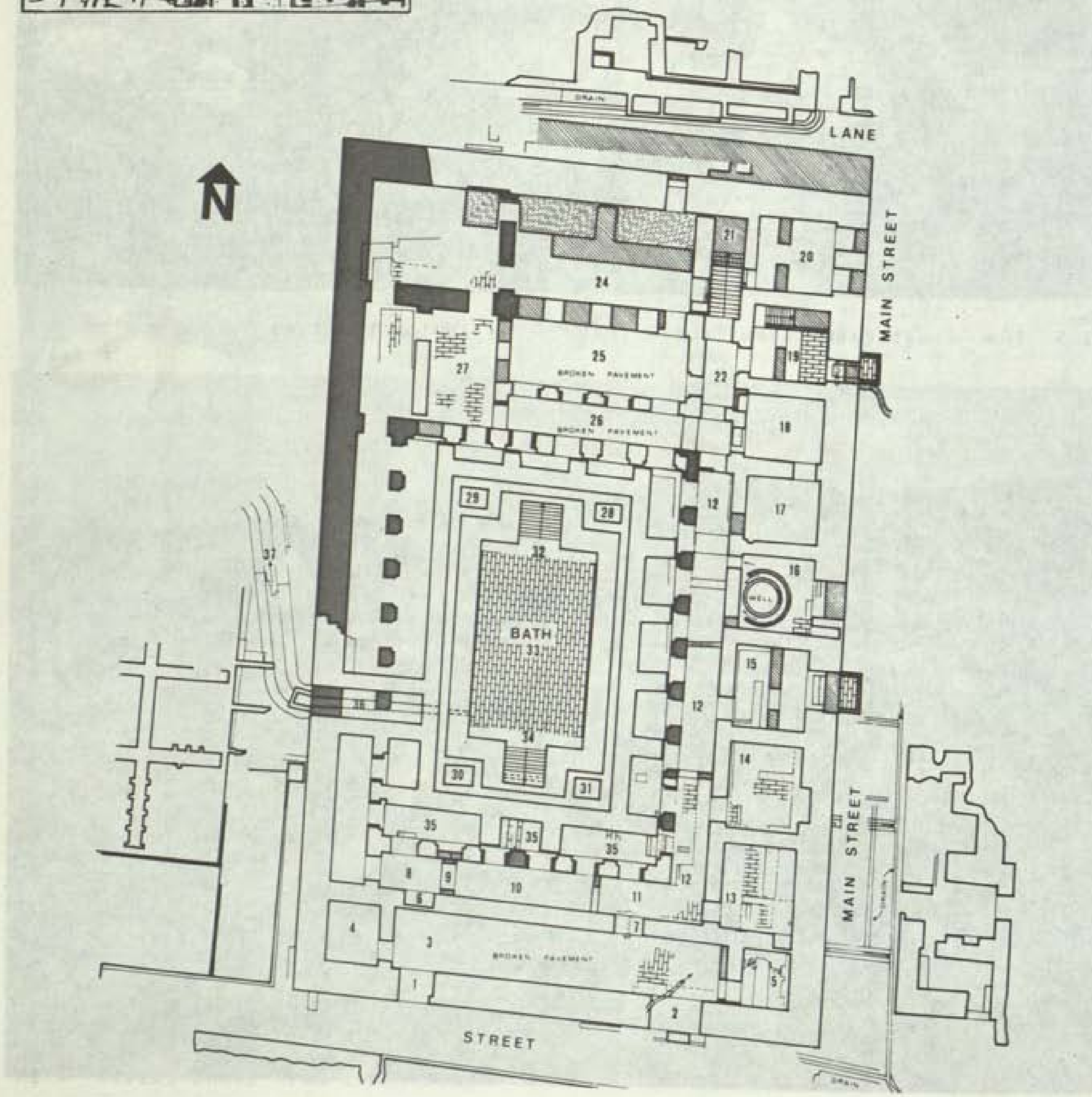
Pl.3 Northern part of citadel

Pl.4 Aerial photo from the South

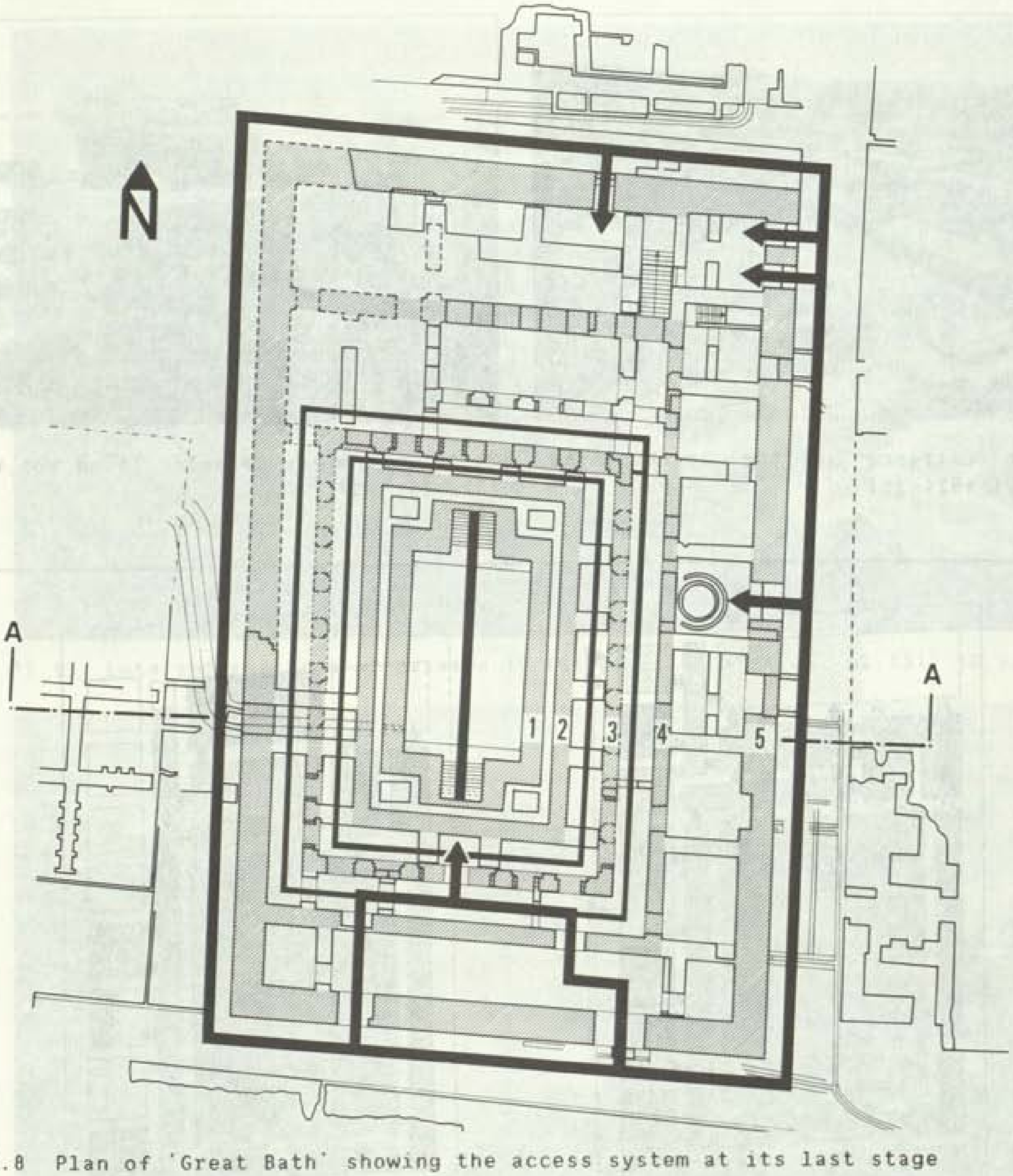
Pl.5 The 'Great Bath', view from N to S a) in the twenties

; and b) 1980

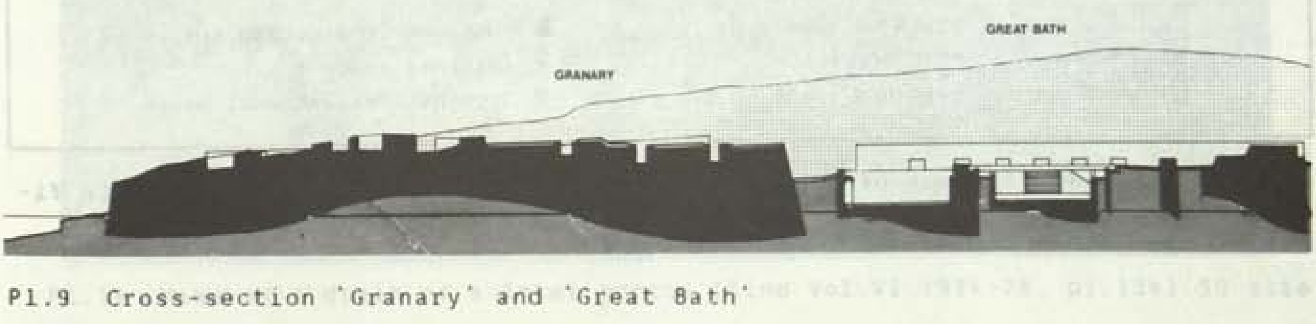
Pl.7 Block 18 DK-G North
Mackay 1938, Pl.XIII



Pl.6 Plan of 'Great Bath' after Marshall 1931, Pl.XXII



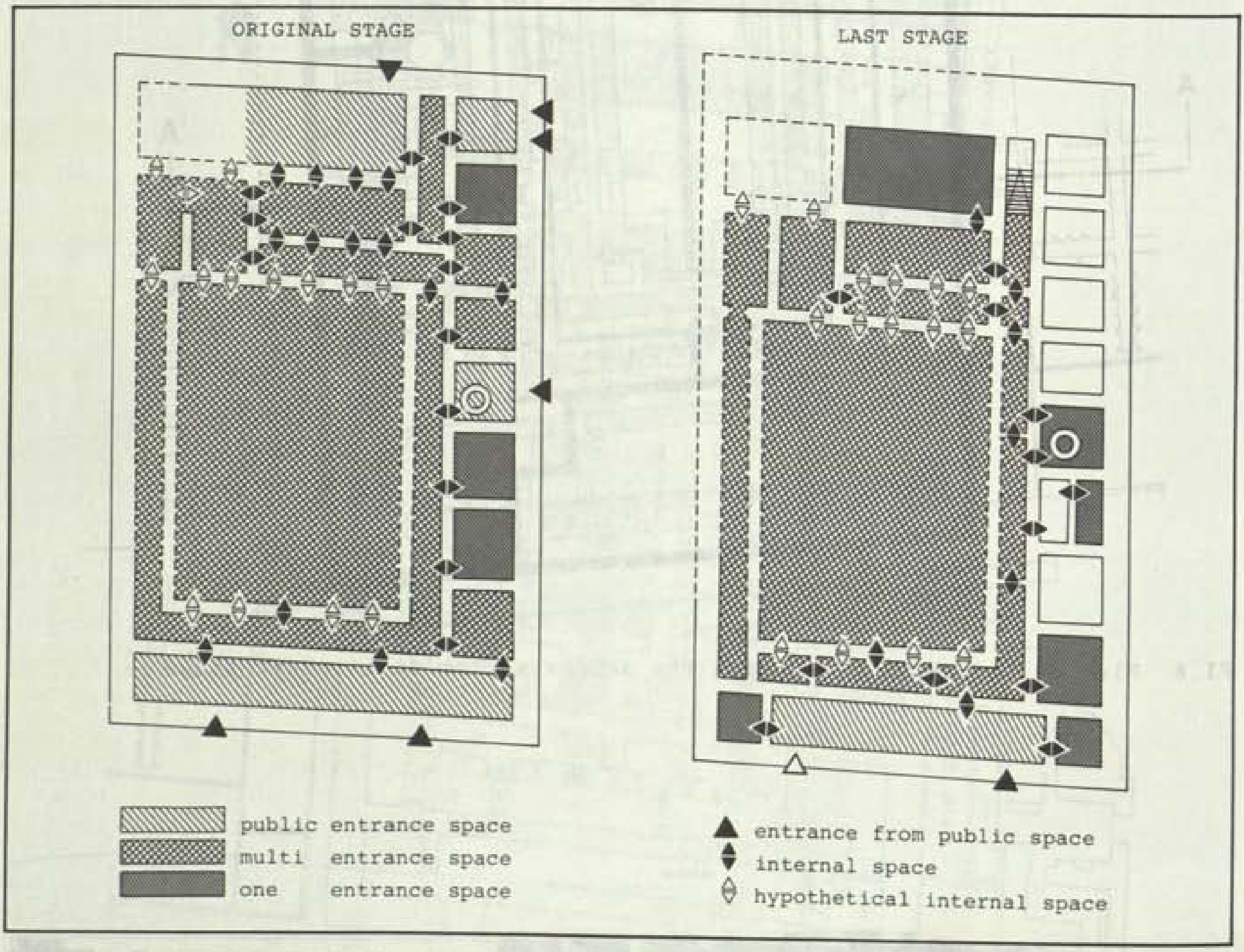
Pl.8 Plan of 'Great Bath' showing the access system at its last stage



Pl.9 Cross-section 'Granary' and 'Great Bath'

Pl.10 Entrance in the South (Sind Vol.VI 1924-25)

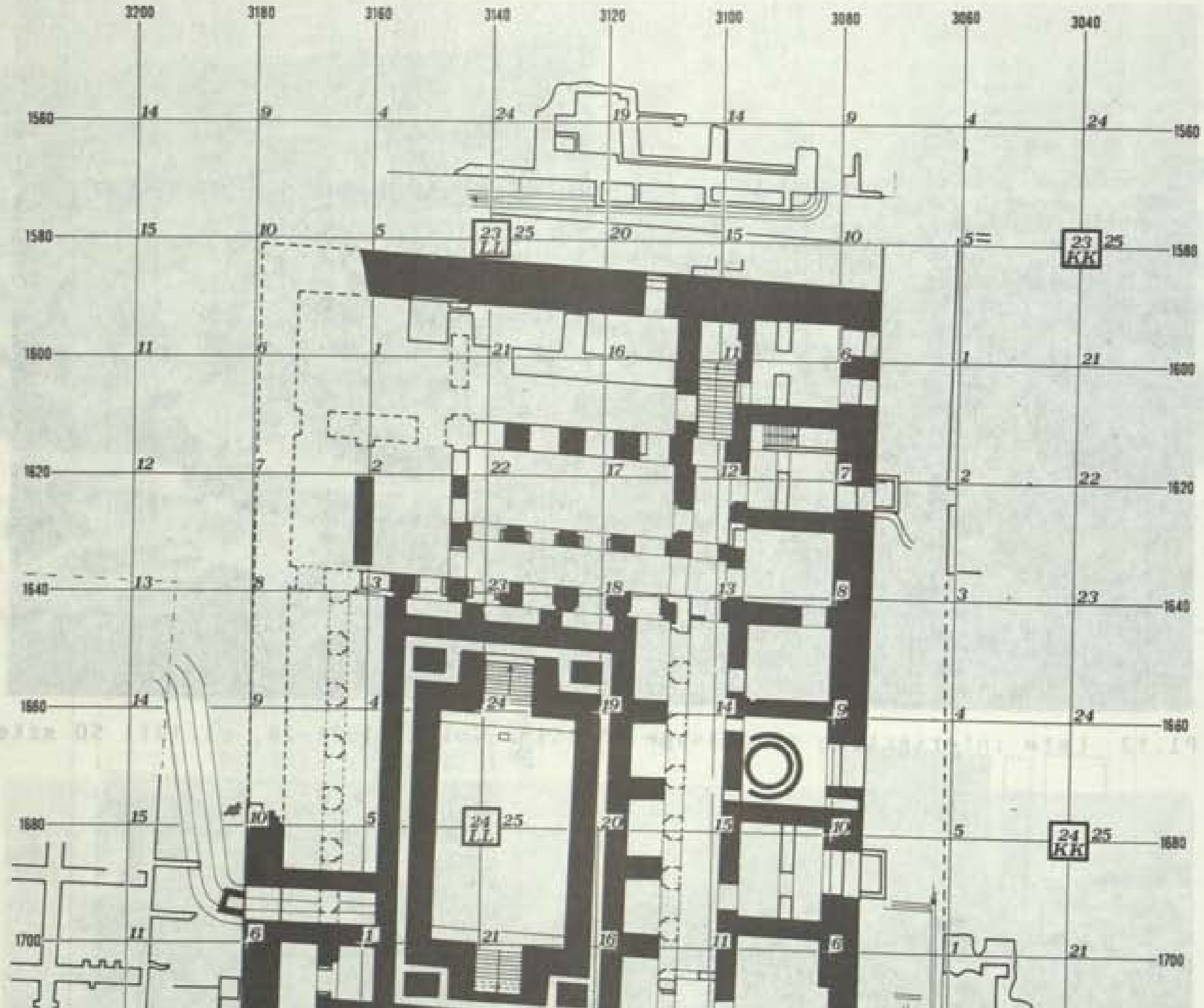
Pl.11 'Funerary vessels' (Sind Vol.VI 1924-25: 157)



Pl.12 Functional systems of access to 'Great Bath' in its original and its final stage

Pl.13 Late intersection of passage 10 (Sind Vol.VI 1924-26, pl.131) SD site

Pl.14 View of a drain of a later period (Sind Vol.VI 1924-26, pl.134) SD site



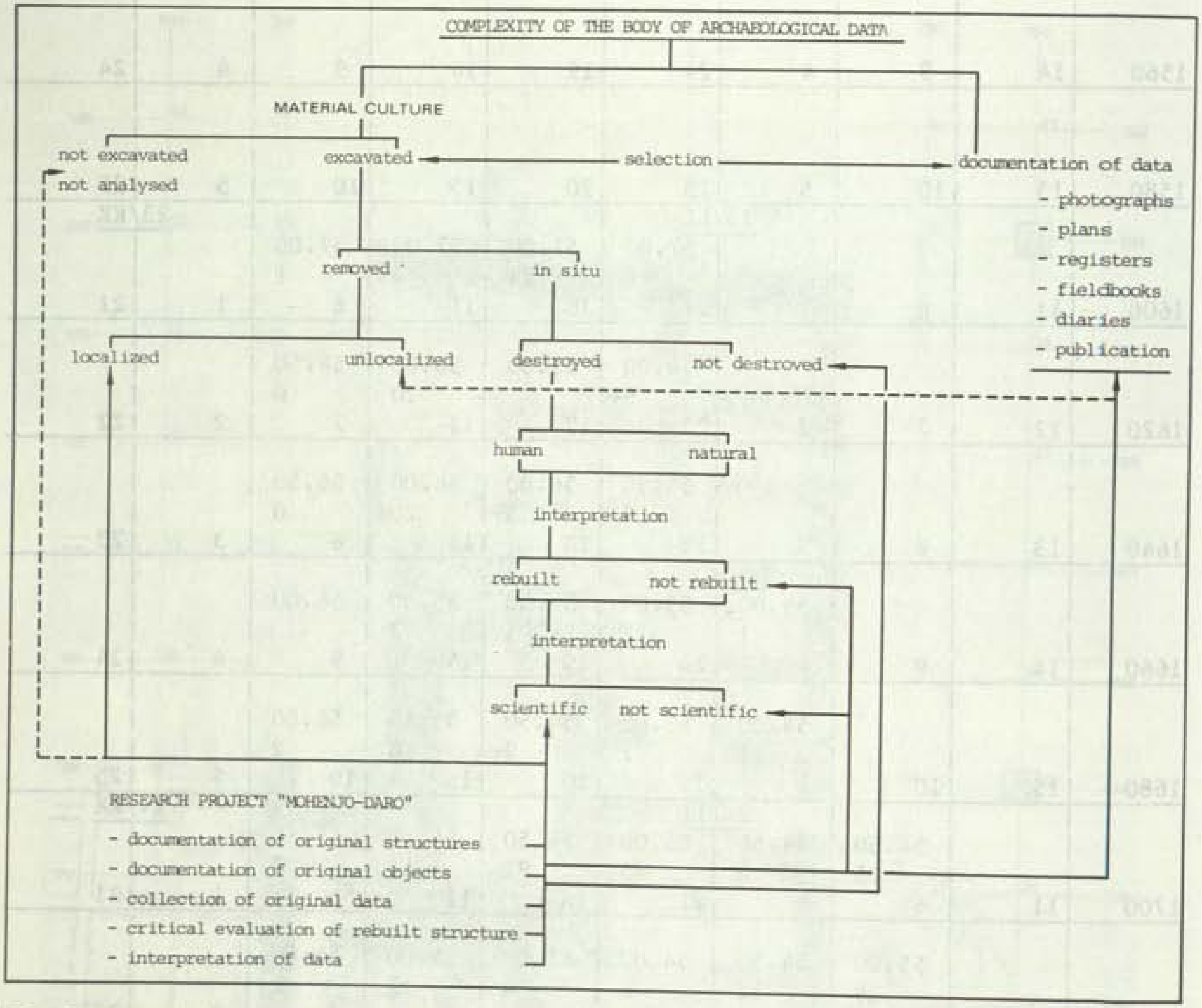
Pl.15 'Great Bath' with excavation grid after reconstruction, showing the numbering of grids and subgrids

	3200	3180	3160	3140	3120	3100	3080	3060	3040
1560	14	9	4	24	19	14	9	4	24
1580	15	10	5	25	20	15	10	5	25
				23/LL					23/KK
1600	11	6	1	57.00 0 21	57.00 21 16	57.00 4 11	57.00 1 6	1	21
1620	12	7	2	56.00 6+ 22	56.00 17	56.00 20 12	56.50 0 7	2	22
1640	13	8	3	55.50 18 23	56.00 5+ 18	56.00 20+ 13	56.50 0 8	3	23
1660	14	9	55.00 1 4	55.00 22 24	55.50 1 19	55.50 2 14	56.00 9	4	24
1680	15	10	54.00 1 5	53.00 7 25	54.50 9+ 20	55.50 18 15	56.00 2 10	5	25
				24/LL					24/KK
1700	11	54.50 15 6	54.50 8 1	53.00 40 21	54.50 92 16	55.00 44 11	55.50 7 6	1	21
1720	12	55.00 29 7	54.50 32 2	54.00 6 22	54.50 4 17	55.00 17 12	56.00 9+ 7	2	22
1740	13	55.00 28 8	54.50 10 3	54.50 14 23	55.00 27 18	55.00 63 13	56.00 21+ 8	3	23
1760	14	55.50 10 9	55.50 21 4	55.50 37 24	56.00 13 19	56.00 20 14	56.00 0 9	4	24
1780	15	10	5	25	20	15	10	5	25
				25/LL					25/KK

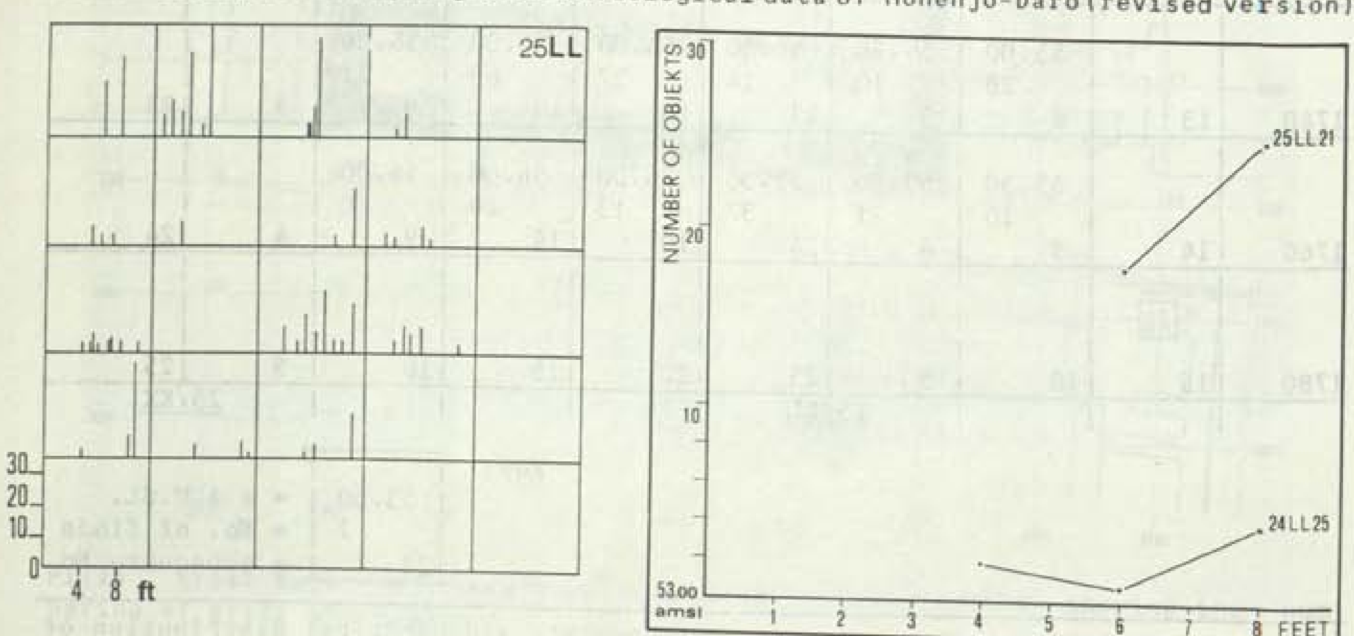
Key:

53.50	= m A.M.SL.
7	= No. of finds
25	= subsquare No.

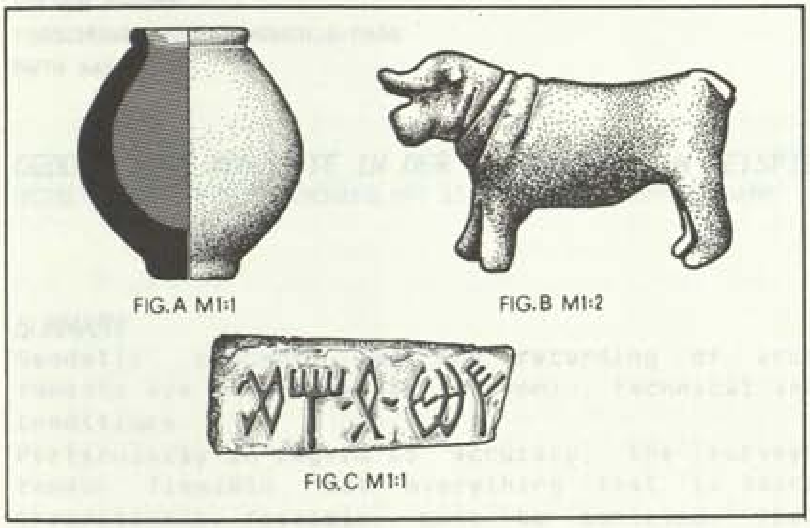
Pl.16 Grid of 'Great Bath' with absolute heights and numerical distribution of finds



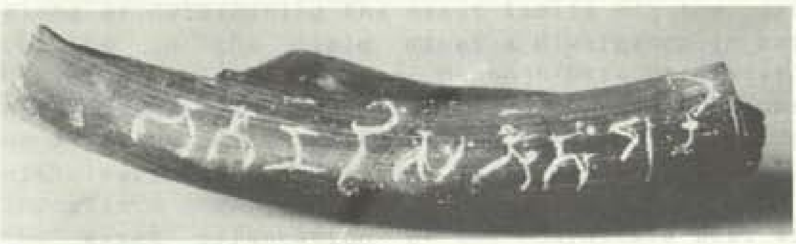
Pl.17 Concept of analyzing the archaeological data of Mohenjo-Daro (revised version)



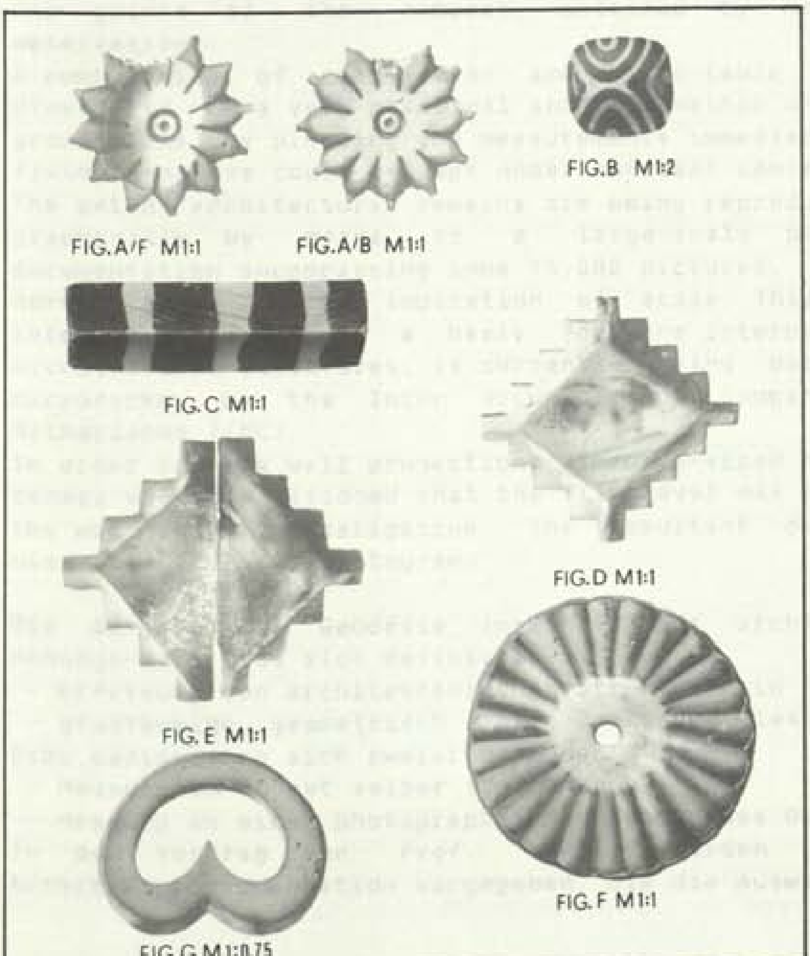
Pl.19 Diagram showing the numerical distribution of objects in relation to their relative depth



Pl.18 a) small pot of celadon 1'1/4" (SD 2390 from Sind Vol.VI 1924-25: pl.205); b) bull (SD 2184 from Sind Vol.XI 1926-27: pl.304) c) seal (SD 1962 from Sind Vol.VIII 1926-27: pl.444)



Pl.20 Brahmi inscribed potsherd (SD 2685 from Sind Vol.XI 1926-27: pl.300)



Pl.21

a) a decorative shell object of star like shape, (SD 2375 from Sind Vol.XII 1926-27: 504);

b) a banded carnelian bead, (SD 1198 from Sind Vol.XII 1926-27: 506);

c) a rectangular piece with red paint & white bands upon it, (SD 1998 from Sind Vol. XII 1926-27: 506);

d) shell object, (SD 2214 from Sind Vol.XII 1926-27: 503);

e) ornamental shell objects for inlay work, (SD 2447 from Sind Vol.XII 1926-27: 503);

f) a faience wheel with spokes inlaid, (SD 1231 from Sind Vol.XII 1926-27: 496);

g) faience object, (SD 1535 from Sind Vol.XII 1926-27: 496);

HOLGER WANZKE
FORSCHUNGSPROJEKT MOHENJO-DARO
RWTH AACHEN

GEODÄTISCHE KONZEPTE IN DER ARCHÄOLOGIE AM BEISPIEL VON MOHENJO-DARO

GEODETIC CONCEPTS IN ARCHAEOLOGY AS APPLIED TO MOHENJO-DARO

SUMMARY

Geodetic concepts for the recording of archaeological remains are determined by economic, technical and political conditions.
Particularly in regard to accuracy, the surveyor has to remain flexible. Not everything that is technically and theoretically feasible, must be achieved. The difficulty alone of determining the exact limits of the architectural objects in the field makes a divergence in accuracy of 1 decimetre in the survey of Mohenjo-Daro permissible.
A topographical survey of the architectural fragments, based on a triangulation net of fixed points, could be carried out with reasonable exactness without special equipment. Of importance here from the archaeological point of view was the exact orientation of the coordinate axes according to the points of the compass, obtained by astronomical observation.
A combination of calculation and plane-table tachymetry proved to be a very practical and fast method of surveying groundplans. By plotting the measurements immediately in the field, progress could be kept under constant control.
The extant architectural remains are being reproduced photographically by means of a large-scale photographic documentation encompassing some 15,000 pictures, using the normed brick as an indication of scale. This material, intended to serve as a basis for the interpretation of architectural structures, is currently being published on microfiche by the Inter Documentation Company BV the Netherlands (IDC).
In order to make wall projections a medium-sized Mamiya M645 camera was so positioned that the film level was parallel to the wall under investigation. The resultant photo can be used directly as a photogram.

Die Aufgabe der Geodäsie innerhalb der archäologischen Dokumentation von Mohenjo-Daro läßt sich definieren als

- Erfassung von architektonischen Strukturen in Form, Lage und Größe;
- großräumige, geometrisch exakte Zuordnung dieser Einzelstrukturen.

Dazu bedient man sich zweier Methoden:

- Messung am Objekt selber (Vermessung);
- Messung an einem photographischen Abbild des Objektes (Photogrammetrie)

In dem Vortrag von Prof. Hektor wurden verschiedene Verfahren der Architekturdokumentation vorgegeben, die die Auswahl und Anwendung der Verfahren

begrenzen.

EINSCHRÄNKUNGEN UND LÖSUNGEN

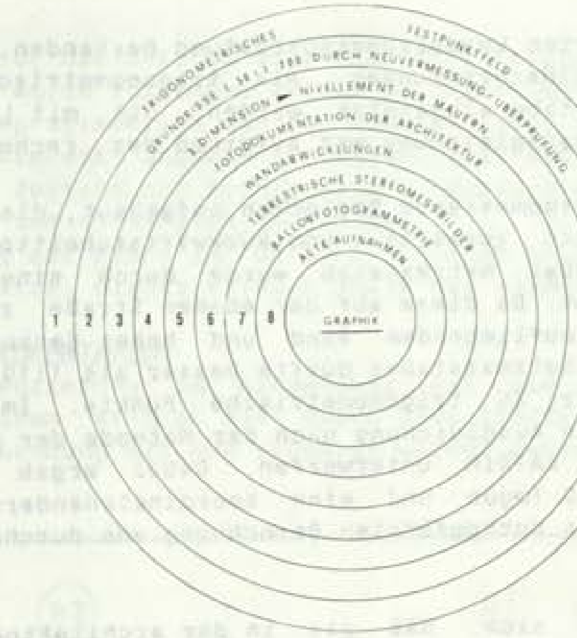
Bei der Suche nach einem optimalen Arbeitskonzept ist Rücksicht zu nehmen auf wirtschaftliche, technische und politische Bedingungen.
Wirtschaftlich werden die Verfahren eingeschränkt durch die begrenzten Sachbeihilfen der DFG. So war es im ersten Jahr nicht möglich, eine photogrammetrische Meßkammer oder einen elektronischen Distanzmesser zu kaufen.
Für jedes Kilo Gepäck, daß per Luftfracht nach Pakistan transportiert wird, sind DM 12,- zu zahlen.

Die Auswahl der Vermessungsgeräte hängt neben den Kosten von technischen Genauigkeitsanforderungen ab. Die Ergebnisse der Architekturdokumentation sollen als Pläne im Maßstab 1:50 und 1:200 dargestellt werden. Das entspricht bei einer Zeichengenauigkeit von 0.2mm einer Genauigkeit von 1 bzw. 4cm in der Natur. Andererseits sind die architektonischen Strukturen vor Ort nicht genauer als +/-(5-10cm) definierbar, da durch Erosion und Salzfraß Mauerecken zerstört sind. Deshalb sind höhere Genauigkeiten technisch sinnlos.
Weiterhin sollte das Vermessungsgerät auch von wenig geübten Kräften zu bedienen sein und universell zu gebrauchen sein, so daß es den vielfachen Anforderungen, die sich im Laufe der Jahre ergeben könnnen, gewachsen ist.

Politische Einschränkungen waren dadurch gegeben, daß in der ersten Arbeitsphase genaue Karten oder Luftbilder nicht zur Verfügung standen oder ein Bildflug hätte durchgeführt werden können. Die vorgesehene Projektdauer von 5 Jahren konnte nie garantiert werden, da einerseits die DFG-Mittel nur jährlich bewilligt werden, andererseits es in Pakistan nie sicher ist, ob jedes Jahr eine neue Arbeitserlaubnis erteilt wird. Selbst bei einem plötzlichen Abbruch des Projektes sollte das bis dahin gesammelte Material für wissenschaftliche Aussagen genügen, wenn auch nicht in differenzierter Form.

Aufgrund dieser Einschränkungen beschafften wir eine Vermessungsausrüstung, die aus folgenden Geräten bestand:
- dem Tachymetertheodoliten KERN DK-RV mit optischer Streckenmessung auf + 2-4cm;
- dem automatischen Baunivellier KERN GKO-A;
- einem Polarkoordinatographen;
- einem Kleincomputer HP41C;
- Maßbändern, Fluchtstäben, einem Winkelprisma;
- sowie einer Mittelformatkamera Mamiya M645 für die photographische und photogrammetrische Dokumentation;

Das Ergebnis der Dokumentation wird in Form einer Hausakte dargestellt. Sie enthält den alten und neuen Grundrißplan 1:50, einen Höhenplan und eine Isometrie. Ergänzt werden kann diese Akte durch Fundregister, Proportionsanalysen etc. Erweitert wird diese Form der Hausbeschreibung durch die vollständige photographische Erfassung der Architektur.
Das methodische Vorgehen für die Erstellung der Dokumentation läßt sich durch ein Ringmodell erläutern.



Tab.1 Ringmodell

Jeder Ring stellt eine abgeschlossene Arbeitsstufe dar, er ist Voraussetzung für den nächsten Ring. Jeder weitere Ring differenziert den vorhergehenden, schafft eine immer detailliertere Architekturdokumentation.

ANLAGE GEODÄTISCHER NETZE

Die wichtigste Aufgabe im ersten Arbeitsabschnitt 79/80 war der Aufbau eines geodätischen Lage- und Höhenfestpunktfeldes. Gefordert war eine sichere Vermarkung und ausreichende Genauigkeit. Dieses Trignetz (DFG 80) sollte in den weiteren Jahren dazu dienen:

- eine Gesamtkartierung des Ausgrabungsgeländes im Maßstab 1:1.000 und 1:2.000 zu erstellen, in der die Architekturfragmente, Straßenachsen und Hausgrundrisse deutlich erkennbar sind;
- die Einzelbereiche HR, VS, SD, DK neu zu vermessen;
- die Ausrichtung von Straßenachsen in Bezug auf die Himmelsrichtungen zu bestimmen, außerdem sind Parallelitäten und Kollinearitäten festzustellen;
- die absoluten, auf Normal Null bezogenen Höhen der Mauerfußpunkte und -kronen zu messen, um Isometrieen zu zeichnen und Daten für stratigraphische Untersuchungen zu gewinnen;
- den Ausgrabungsbereich durch Luftbildphotogrammetrie aufzunehmen und dazu eine Paßpunktgrundlage zu schaffen.

Schon in den 20iger Jahren wurde von dem englischen Vermesser Francis ein 100' Raster für Mohenjo-Daro angelegt. Da er nicht dauerhaft vermarkt wurde, gelang es bisher nicht, ihn zu rekonstruieren. Daher sollte unser TP-Netz für archäologische Arbeiten, die in Zukunft durchgeführt werden, möglichst noch erhalten sein, um die Existenz verschiedener Koordinatensysteme zu vermeiden. Für Festpunkte, die in den Ausgrabunsbereichen liegen, besteht die Gefahr, daß sie bei neuen Ausgrabungen oder Restaurierungen zerstört werden. Aus diesem Grund liegen einige TP auf den Schutzdämmen und an der Straße zum Flughafen, ein Antennenmast dient als Hochziel. Für den nächsten Arbeitsabschnitt ist geplant, markante, mit hoher Wahrscheinlichkeit unzerstörbare Architekturpunkte als Sicherunspunkte zu vermessen (Ecken des Großen Bades und Museums).

Aufgrund der improvisierten Vermessungsausrüstung bestanden bei der Planung des Trignetzes erhebliche Einschränkungen. Als trigonometrische Signale mußten zusammengesteckte Fluchtstäbe eingesetzt werden, die mit Lotschnur abgespannt wurden. Eine strenge Netzausgleichung war aufgrund des rechnerischen Aufwandes nicht möglich.

Das Trignetz wurde aus ausgemessenen Dreiecken aufgebaut, die Widersprüche lagen bei +/-1.5mgon. Über ein Vorwärts- und Rückwärtsschnittprogramm konnten die Punkte berechnet werden. Der Netzmaßstab wurde durch eine 600m lange, direkt gemessene Strecke bestimmt. Da diese auf der ebenen Straße zum Flughafen lag, war eine Messung mit aufliegendem Band und hoher Genauigkeit möglich. Die relative Genauigkeit des Netzmaßstabes dürfte besser als $1:10^{-4}$ sein.

Insgesamt umfaßt das Netz 26 trigonometrische Punkte. Im Oktober 1981 wurde dieses Netz einer strengen Ausgleichung nach der Methode der kleinsten Quadrate mit dem Programmsystem KATRIN unterworfen. Dabei ergab sich ein mittlere Richtungsfehler von +/-0.7mgon und eine Koordinatenänderung gegenüber der näherungsweise in Pakistan duchgeführten Berechnung von durchschnitlich 2-3cm.

EINZELPUNKTAUFNAHME

Bei der Feldarbeit zeigte sich, daß das in der architektonischen Bauaufnahme gebräuchliche Bogenschlagverfahren zu ungenau ist, da die Punkte in der Natur schlecht definiert sind und somit eine sehr ungünstige Fehlerfortpflanzung besteht.

Andererseits ist die Zahlentachymetrie für kleinteilige Strukturen zu aufwendig. Wir entschlossen uns zu folgendem Vorgehen:

In dem zu vermessenden Bereich werden Aufnahmepunkte (AP) im Abstand von ca.15m lokal vermarkt und durch einen Polygonzug koordinatenmäßig bestimmt.

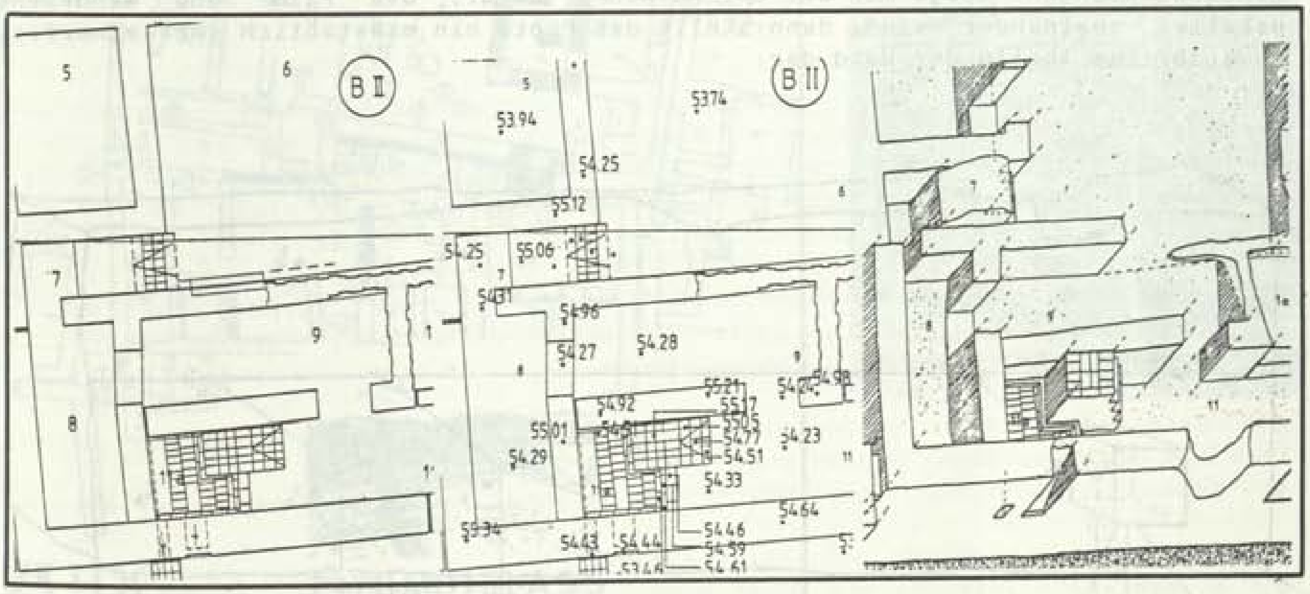
Die Eckpunkte der Architektur werden mittels Theodolit und Bandmaß polar vermessen und direkt im Feld mit einem Polarkartameter auf Polyesterfolie gezeichnet. Von diesen Punkten aus werden Details (Eingänge, Fugen, Nischen) mit dem Zollstock eingemessen. Dieses Verfahren ist genau und sicher, da die Punkte unabhängig voneinander bestimmt werden, Fehler werden direkt im Feld erkannt. An Personal werden zwei Fachkräfte und ein Meßgehilfe benötigt.

Abb.1 Tachymetrie

Für die Bereiche, für die bereits alte englische Originalpläne aus den zwanziger Jahren existieren, wurde folgendes Verfahren angewendet:
die Pläne wurden reprographisch auf den Maßstab 1:200 gebracht und im Feld auf geometrische Richtigkeit überprüft. Waren sie noch exakt, so wurde in diese Pläne der aktuelle Zustand der Architektur eingezeichnet. Dieses Verfahren wurde erfolgreich im HR- und VS-Bereich angewendet.
Bei der Überprüfung der Pläne im DK-B,-C Bereich zeigt sich ein starker Verzug von ca.3m in der Natur, dieser Bereich wurde neu vermessen.

PHOTOGRAPHISCHE DOKUMENTATION

Die nächste Differenzierung im Ringmodell ist die Darstellung der dritten Dimension. Zum einem erfolgt dies durch nivellierte Höhen der Mauerkronen und -fußpunkte. In Verbindung mit dem Grundriß werden daraus Isometrieen gezeichnet:



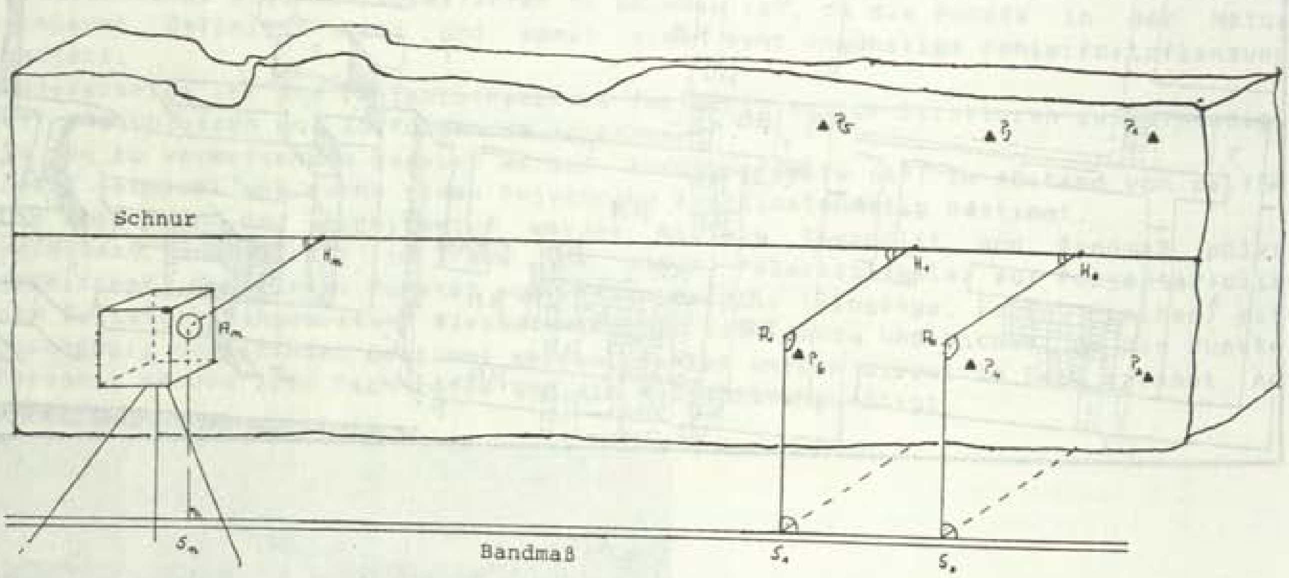
Zum anderen gelingt die vollständige visuelle Darstellung der dritten Dimension nur durch die Photographie/-grammetrie. Das Meßbild liefert gegenüber dem "normalen" Photo den Vorteil, zusätzlich zur visuellen Erkennung Maßinformation zu liefern.
Daß wir uns trotzdem für das Photo entschieden haben, hat folgende Gründe:
- Die photographische Dokumentation soll begleitend zu den Grundrissen und Isometrien die Architekturfragmente vollständig erfassen, um den heutigen Zustand eindeutig für alle Zeit festzuhalten.
- Der Ziegelstein ist in seiner normierten Größe ein immer wiederkehrender Maßstab in jedem Photo, mit seiner Hilfe können Gebäudegrößen abgeschätzt werden.
- Das Material soll durch eine Publikation einem weiten Benutzerkreis zugänglich gemacht werden.

Ergänzt wird dieses Photomaterial durch alte Originalaufnahmen aus den zwanziger Jahren, die in Archiven von Karachi und Delhi entdeckt wurden.
Damit lassen sich Änderungen der Architektur belegen, Abweichungen des heutigen Zustandes von der Originalstruktur können sicher erkannt werden und die Mauern hinsichtlich ihres Rekonstruktionszustandes klassifiziert werden.

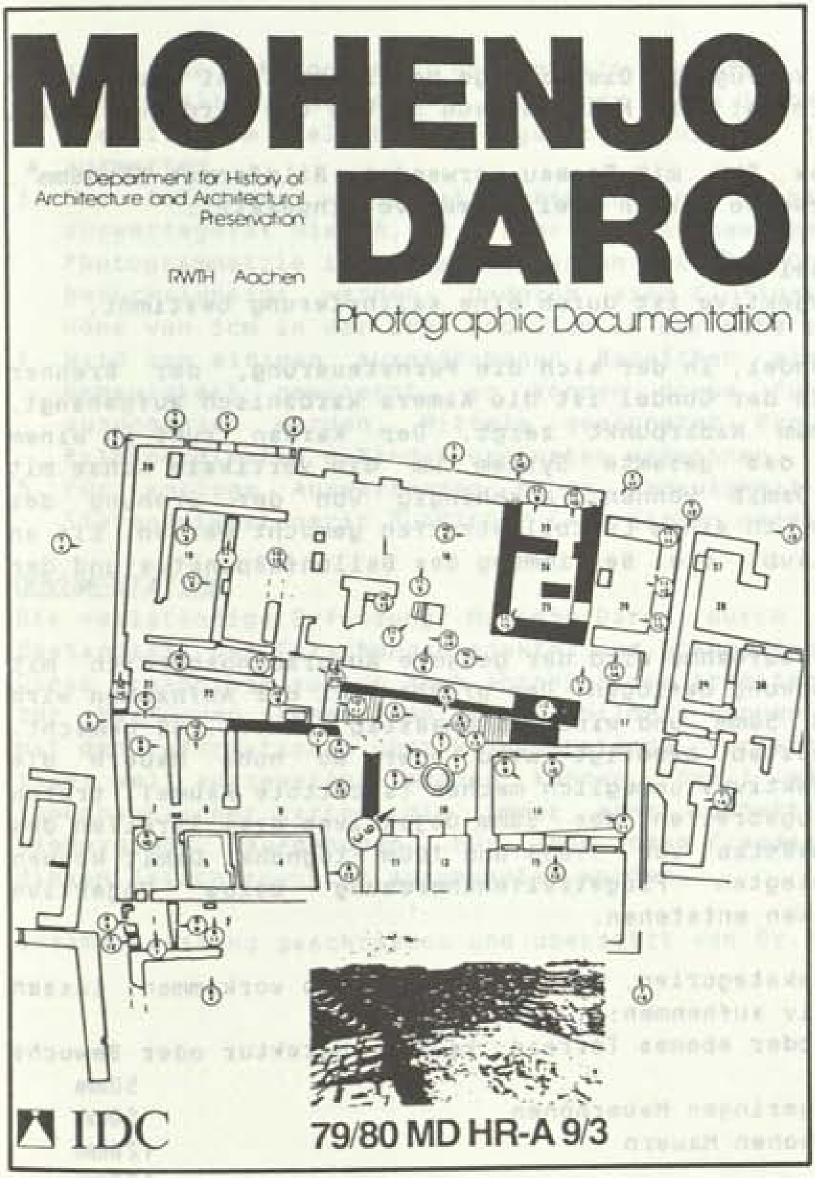
Die Menge des Photomaterials (ca.15.000 Aufnahmen) schließt eine Publikation in Buchform aus, die Kosten wären viel zu hoch. Wir haben uns daher entschlossen, das Bildmaterial auf Mikrofichen zu veröffentlichen, die Inter Documentation Company (IDC) wird die ersten 2.000 Aufnahmen im März '82 herausgeben. Der Mikrofichesammlung sind Pläne im Maßstab 1:200 beigefügt, aus denen Aufnahmestandpunkte und -richtungen zu erkennen sind.

WANDABWICKLUNG

Diese Photodokumentation wird erweitert durch Meßbilder in Form von Wandabwicklungen. Sorgt man bei der Aufnahme dafür, daß Film- und Wandebene parallel zueinander sind, dann stellt das Photo ein maßstäblich verkleinertes, unverzerrtes Abbild der Wand dar:



Darin lassen sich Strukturen, die für stratigraphische Analysen von Bedeutung sind, abmessen.
Die geforderte Parallelität läßt sich durch einfache Absteckungsverfahren erreichen, eine mitphotographierte Nivellierlatte ergibt den Bildmaßstab. Verzeichnungsfehler der für diesen Zweck verwendeten Mamiya M645 werden kaum wirksam, da der Bildmaßstab bei 1:70-1:200 und der Auswertemaßstab bei 1:50 liegt.



ZIEL

In der Arbeitsphase '82/'83 ist geplant, das Ausgrabungsgebiet aus der Luft zu vermessen. Dabei sollen von einem ferngesteuerten Heißluftfesselballon aus Aufnahmen aus verschiedenen Höhen gemacht werden. Ziel ist es:

- eine Luftbilddokumentation von hoher Genauigkeit des gesamten Ausgrabungsbereiches zu erstellen, den Zustand Mohenjo-Daros im Jahre 1982 einwandfrei festzuhalten, der als Basis für weitere Forschungen dient;
- von einigen ausgegrabenen Bereichen, die aufgrund ihrer Architektur nur schlecht mit dem Theodolit zu vermessen sind (DK-G), Grundrißpläne und Isometrien im Maßstab 1:200 zu erstellen;
- die Oberflächenanalyse, die in diesem Jahr am Boden durchführt wird, durch detailreiche Luftaufnahmen zu unterstützen insbesonders Bodenverfärbungen sichtbar zu machen;
- Architekturstrukturen, die durch die Bodenerosion freigelegt worden sind und bisher nicht vermessen wurden, zu erfassen;
- durch Stereoschrägaufnahmen einem Benutzer der Dokumentation einen plastischen und vollständigen Eindruck des Ausgrabungsgebietes zu geben.

Aus politischen und wirtschaftlichen Gründen steht in Pakistan kein Bildflugzeug

oder ein Hubschrauber zur Verfügung. Die einzige Möglichkeit ist der Einsatz eines Heißluftfesselballons. Er hat eine Nutzlast von 5-10kg und wird durch drei Seile vom Boden aus gesteuert.
Als Kamera wird eine Rolleiflex SLX mit Reseau verwendet, Bildformat $56x56mm^2$.
Für die verschiedenen Einsatzzwecke werden zwei Objektive eingesetzt:

- 4/50mm DISTAGON Bildwinkel 76°
- 5.6/120mm S-PLANAR Bildwinkel 36°

Die innere Orientierung der Objektive ist durch eine Kalibrierung bestimmt.

Unter dem Ballon hängt eine Gondel, in der sich die Fernsteuerung, der Brenner und die Gasflasche befinden. In der Gondel ist die Kamera kardanisch aufgehängt, damit die optische Achse zum Nadirpunkt zeigt. Der Kardan ruht in einem Drehkranz, der es ermöglicht, das gesamte System um die vertikale Achse mit einem Elektromotor zu drehen. Damit können, unabhängig von der Drehung des Ballons, parallele Aufnahmen in einem Luftbildstreifen gemacht werden. Ein an der Gondel montiertes Lot erlaubt die Bestimmung des Ballonfußpunktes und der Höhe über dem Boden.

Für die photogrammetrische Luftaufnahme wird der gesamte Ausgrabungsbereich mit Streifen von 60% Längsüberdeckung beflogen. Der größte Teil der Aufnahmen wird aus 60m Höhe mit dem DISTAGON 50mm und einem Bildmaßstab von 1:1.200 gemacht. Dort, wor ein größerer Bildmaßstab benötigt wird oder wo hohe Mauern die Verwendung eines Weitwinkelobjektives unmöglich machen (sichttote Räume), treten an die Stelle von zwei Flugstreifen des 50mm Objektives drei Streifen des S-PLANAR 120mm mit einem Bildmaßstab von 1:833 und 100m Flughöhe. Damit können innerhalb der einmal festgelegten Flugstreifenanordnung beide Objektive verwendet werden, ohne daß Lücken entstehen.

Die unterschiedlichen Geländekategorien, die in Mohenjo-Daro vorkommen, lassen sich mit dem jeweiligen Objektiv aufnehmen:

A - Offenes, leicht hügeliges oder ebenes Terrain, kaum Architektur oder Bewuchs
B - Ausgegrabene Bereiche mit geringen Mauerhöhen 50mm
C - Ausgegrabene Bereiche mit hohen Mauern 50mm
D - Stark bewachsenes Gelände 120mm
E - Gebiete mit Oberflächenfunden 120mm
F - Schrägaufnahme Übersicht 50mm sonst 120mm
50mm

Für die Meßbilder wird der S/W-Film AGFAPAN 100 genommen, für Übersichts- und Schrägaufnahmen der EKTACHROME 64.

Vor der Aufnahme werden am Boden gedruckte Paßpunkte ausgelegt und vermessen. In bebauten Gebieten können auch gut definierte Gebäudeecken verwendet werden. Für jede Aufnahme wird eine Karteikarte angelegt, auf der alle Paßpunkt- und Aufnahmeinformation eingetragen werden.
Nach der Entwicklung der Bilder wird auf der Karteikarte ein $12x12cm^2$ großer Abzug aufgeklebt.

AUSWERTUNG

Die geodätische Auswertung der Luftaufnahmen kann auf vier verschiedenen Wegen erfolgen:

1. Es werden Abzüge im Format $20x30cm^2$ angefertigt. Sie dienen zur Interpretation unter dem Stereoskop. Punktweise können auch Strukturen durch ein Möbiusnetz übertragen werden.
2. Von einigermaßen ebenem Gelände können mit dem Entzerrungsgerät SEG5 maß-

stäbliche Fotopläne hergestellt werden. Dazu sind vier Paßpunkte erforderlich, die in etwa gleicher Höhe liegen sollen. Besonders Aufnahmen, die mit dem Teleobjektiv gemacht wurden, lassen sich auf diese Weise auswerten.

3. Die Aufnahmen werden allgemein in einem mechanischen oder optischen Stereoauswertegerät wie A8, C8, Planimat ausgewertet, da dieses am Institut für Photogrammetrie in Aachen vorhanden ist. Die Objektivverzeichnung kann nicht berücksichtigt werden. Dadurch sind Einflüsse der systematischen Fehler in Höhe von 5cm in der Lage und 15cm in der Höhe zu erwarten.
4. Wird von einigen ausgegrabenen Bereichen eine punktweise Auswertung hoher Genauigkeit gewünscht, so können diese Punkte am Stereokomparator PSK ausgemessen werden. Mittels geeigneter Programme lassen sich aus den Bildkoordinaten Geländekoordinaten errechnen.
5. Für analoge Auswertungen hoher Genauigkeit können mit dem analytischen Stereoauswertegerät PLANICOMP C100 Karten gezeichnet werden.

DOKUMENTATION

Die vollständige Erfassung Mohenjo-Daros durch Stereoluftbilder ist wichtiger Bestandteil des Forschungsprojektes zur Dokumentation der Architektur. Diese Ergebnisse sollen nach Abschluß der Arbeiten der internationalen Fachwelt zur Verfügung stehen. Von den Luftbildern können Kopien hergestellt werden, die mit den Informationen über Reseauabstände, Verzeichnung, Kammerkonstante etc. in aller Welt ausgewertet werden können. Damit wäre der Nachteil herkömmlicher topographischer Karten, die immer eine subjektive Betrachtung des Geländes wiedergeben, aufgehoben. Für jede neue Fragestellung kann das Material unter diesen Gesichtspunkten ausgewertet werden.

Zusammenfassung geschrieben und übersetzt von Dr.M.Mulloy

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ARCHAEOLOGICAL FIELDWORK IN AFGHAN SISTAN AND CURRENT RESEARCH ON EASTERN IRANIAN ARCHITECTURE

ARCHÄOLOGISCHE FELDARBEIT IM AFGHANISCHEN SISTAN UND LAUFENDE UNTERSUCHUNGEN OSTIRANISCHER ARCHITEKTUR

ZUSAMMENFASSUNG

Von 1969-1974 führte das Seminar für Orientalische Kunstgeschichte der Universität Bonn in Zusammenarbeit mit naturwissenschaftlichen Instituten eine archäologische Landesaufnahme in Afghanisch-Sistan durch. Dabei wurden im Gebiet der Wanderdünen die alten Bewässerungsanlagen als Grundlage einer Besiedlung von der vorgeschichtlichen bis zur islamischen Zeit kartiert. Denkmäler orientalischer Baukunst sind vor allem vom 10.-14.Jh. erhalten.

The Iranian and Afghan parts of Sistan (Fig.1) have been explored from about 1900 onwards by British geographers, French archaeologists, American prehistorians and Italian orientalists. These scholars discovered prehistoric cities, Achaemenian areas of settlement, Scythian implements, Sasanian coins and the ruins of numerous Islamic towns. The present Afghan province of Nimruz with its capital of Zaranj corresponds to the eastern part of the historical cultural province of Sistan. In this land of semi-desert and moving sand dunes the people were dependent on artificial irrigation: especially the Hilmend and, to a lesser degree, the Khashrud rivers fed an extensive canal system. Greek, Roman, Arabic and Persian writers mention numerous fortresses, villages and towns near these water courses. Rivers, canals, towns and villages in Sistan were also known to cartographers of the Middle Ages and modern times. In prehistoric and historical times the Hilmend river shifted its delta from south to north. Scientists, orientalists and archaeologists have studied the history of settlement in Afghan Sistan and Iranian Sistan. From 1968-1978 the Research Department of Oriental Art History, Bonn University, carried out field surveys in the northern parts of Afghan Sistan in cooperation with the Director General of Archaeology and Conservation of Historical Monuments, Kabul, and various foreign and German colleagues, especially from the Department of Palaeontology, Geological Institute, University of Cologne.

Ruins marked on the new sheets prepared by the Cartographic Institute, Kabul, as "Dewale Khodaydad" were chosen for detailed research. A botanist located the ancient irrigation system and the ecological conditions of the medieval settlement. A hydrologist traced the historical irrigation network. A surveyor drew the plan of the rural estate; its farm houses are orientated towards the north-west (Fig.2), i.e. the direction of the prevailing "wind of the 120 days" (about June-September). After studying the ground plan, elevation and sections of an Islamic ivan-courtyard house, an architect reconstructed its original form (Fig.3). A photogrammetrist measured out various groups of mud-brick ruins (Fig.4). It may be mentioned that the Institute of Photogrammetry at the RWTH Aachen assisted us in every respect. The Ministry of Mines, Kabul, supplied air photographs taken for the current geological mapping of the country; they proved to be of additional value for archaeologically based topographical research (Pl.1).

Archaeological find maps showing recently discovered ruins were drawn up by members of the Institute of Cartography and Topography, Bonn University, with the help of aerial photography (Pl.2). It appears, for example, that Poste Gaw would deserve full-scale excavation and might reveal pre-Islamic settlements.

The photogrammetrists cooperated with the surveyors (Fig.2, Pl.3) as well as with the architects (Fig.3, Pls.4-8). The majority of ruins were reached by landrover (Pls.5, 6); structures blocked by moving sand dunes were conveniently approached on horseback (Pl.8). Through the combined efforts of technicians and historians we came to the conclusion that the surviving oriental building types in medieval Islamic palace-like dwellings date from the 10th to the 14th centuries. This dating could be supported by surface finds of coins and pottery.

Remains of rural settlements are located in the surroundings of irrigation systems. At Dewal-i Khodaydad (Fig.2) one particular kind of mud-brick structure appears to be typical: a rectangular enclosure measuring 10x30m approx., usually orientated towards north-west, containing in the centre of the north-western part a barrel-vaulted ivan flanked by double-storeyed towers, whilst on the other sides single-storeyed square rooms crowned by squinch domes surround an open "ivan-courtyard" (Fig.3). This type of the so-called ivan -Hofhaus (after Diez and Oelmann) derives from Parthian prototypes at Assur and Hatra and is similarly known from Ghorid Afghanistan, where there is an undefended Islamic residence at Bamiyan. About 20 houses of this type form the settlement of Dewal-i Khodaydad which is situated amongst canals and irrigated fields. Domed buildings served as cisterns (Fig.4) and guaranteed the continuity of rural life. Ancient oriental decorative motifs incorporated in a system of pilasters and niches - known, for example, from Sasanian Ctesiphon to Abbasid Ukhaidir - were re-used in the palatial buildings of the powerful landlords in country estates, and can still be seen today in Cegini (Fig.3, Pl.4).

In these and other ruins we discovered coins minted under Islamic dynasties of the 12th to 15th centuries AD (e.g. "Nimruz" on a coin issued under 'Iss al-Haqq wa l-din, 1352-1382), inscriptions of the 13th and 14th centuries AD and pottery from the 10th to 18th centuries. According to Islamic historians and geographers such as al-Maqdisi (306), there were few cities in contemporary Sistan but numerous rural estates ("rustaq"); they are enumerated in medieval source books. We believe that we have discovered some of them in various ruins: groups of about 20 houses with an open central court and a large, barrel-vaulted ivan on the north-western side; these settlements were situated near fields irrigated by canals branching off via brick constructions. In the past, Sistan was known as a fertile land and consequently its fields and villages were a constant temptation to invaders from the middle of the 1st millennium BC till after the middle of the 2nd millennium AD. After each devastation the irrigation systems and settlements were rebuilt. Historians tell us that from 253 H/867 AD till aout 900 H/1495 AD the native dynasty of the Saffarids either ruled independently or supplied governors and vassals under the rule of the Ghaznavids, Ghorids, Saljuqs, Il Khans and Timurids, and that after 1508 AD local families again took over the rule of Sistan on behalf of the Safavids, also in new administrative centres. But after the destruction of dams during the 14th and 15th centuries settlement in Sistan was confined to areas near water courses where even a reduced population could maintain a limited irrigation system. It is only after the 17th-18th centuries that human devastation seems to have finally made systematic recultivation impossible, for the population was no longer able to keep moving sand dunes off the fields, to rebuild dams and canals or to sink new wells. A comparison of the building forms of the mud-brick ruins, still visible today, with information gathered from inscriptions, coins and pottery leads to the preliminary conclusion that the mojority of watch towers, fortresses, rural

estates ("rustaq"), "open" (unwalled) towns situated in the plain and fortified cities existed from the beginning of the 12th to the end of the 15th century.

Each member of the team published his observations in the relevant scientific journals and also contributed to the comprehensive joint final publication. In all fields of research we collected so much new material on the spot that we were able to continue publishing even after 1979 when, due to political upheaval and military operations, the Sistan region like all other Afghan provinces was closed to further field work. Meanwhile, we can only hope that peaceful international relations will be restored, thus allowing us to finish the thermoluminescence dating begun for us in the Iranian-Afghan borderland by the Research Laboratory for Archaeology and the History of Art, Oxford University.

In view of this situation, we have called our first publication a "preliminary final report":
Nimruz. Geländebegehungen in Sistan 1955-1973 und die Aufnahme von Dewal-i Khodaydad 1970. Hrsg. v. Klaus Fischer in Zusammenarbeit mit D. Morgenstern u. V. Thewalt. Band 1-2. Bonn: Rudolf Habelt Verlag, Am Buchenhang 1, 1974-76. (Veröffentlichungen des Seminars für Orientalische Kunstgeschichte der Universität Bonn. A, 1 - 2.) 1. Text. 1976. DM 120,-. 2. Tafeln, Karten, Pläne. 1974. DM 86,-.

There follows a select bibliography of publications by participants in the fieldwork, partly already incorporated in "Nimruz 1 2", partly in preparation for inclusion in further volumes of the Nimruz series:

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3. Fischer, K.: Projects of archaeological maps from Afghan-Sistan. Zentralasiatische Studien 4, 1970.
4. Id./Mauelshagen, L./Tönnessen, K.: Photogrammetrische Aufnahme schwer zugänglicher Ruinen im Orient. In: Architektur Photogrammetrie II.Internationales Symposium für Photogrammetrie in der Architektur und Denkmalpflege, Bonn 1976. Landeskonservator Rheinland, Arbeitsheft 17.
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7. Id.: Archäologische Forschungen in Afghanistan 1974 -1978. In: Neue Forschungen in Afghanistan. Hrsg. v.C.Rathjens. Opladen 1981.
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10. Forstner, M.: Sistan während des Kalifats des Abbasiden al-Musta'in (248/862 - 252/866) nach dem Tarih-i Sistan. Der Islam 48, 1971.
11. Hünerfeld, Lothar: Luftbildinterpretation als optimale Vorbereitung der Feldarchäologie, dargestellt am Beispiel Afghanisch-Sistan. 20.Deutscher Orientalistentag, Erlangen 1977. ZDMG, Suppl. Wiesbaden 1980.
12. Kempf, E.K.: Quartärgeologische Forschungen im Seistan. In: Neue Forschungen in Afghanistan. Hrsg. v.C.Rathjens. Opladen 1981.
13. Klinkott, M.: Hürdenhäuser in Afghanistan. Architectura 6, 1976.
14. Id.: Islamische Baukunst in Afghanisch-Sistan. Mit einem geschichtlichen Überblick von

Alexander dem Großen bis zur Zeit der Safawiden-Dynastie. Dietrich Reimer Verlag. DAI-Abteilung Teheran = Archäologische Mitteilungen aus Iran, Ergänzungsband 8. Berlin 1982.
15. Mauelshagen, L./Morgenstern, D.: Geodätische Arbeiten bei archäologischen Untersuchungen der Ruinenfelder in Afghanisch-Sistan. Vermessungswesen und Raumordnung, Vermessungstechnische Rundschau 35, 1973.
16. Radermacher, H.: Historical irrigation systems in Afghan Sistan - their origin, their decline and possibilities of their reconstruction. ICID (Intern. Comm. on Irrigation and Drainage), July 1974.
17. Id.: Historische Bewässerungssysteme in Afghanisch-Sistan: Gründe für ihren Verfall und Möglichkeiten ihrer Reaktivierung. Kulturtechnik und Flurbereinigung 16, 1975.
18. Reuther, H.: Die Lehmziegelwölbungen von Gol-i Safed. Versuch einer Typologie. Archäologische Mitteilungen aus Iran, N.F.6, 1973.
19. Tosi, M.: Excavations at Shahr-i Sokhta, a chalcolithic settlement in the Iranian Sistan. Prelim. Report on the 1st Campaign 1967. East and West, N.S. 18,1/2. 1968.
20. Id.: The Lapis Lazuli trade across the Iranian plateau in the 3rd millennium BC. In: Gururajamanjarika 1. 1974.

In recent years further research on Sistan and adjacent areas has been published by colleagues cooperating with us:

21. Amiet, P./Tosi, M.: Phase 10 at Shahr-i Sokhta: Excavations in Square XDV and the Late 4th Millennium BC. Assemblage of Sistan. East and West 28, 1978.
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25. Elfenbein, J.: Report on a linguistic mission to Helmand and Nimruz. Afghan Studies 2, 1979.
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29. Id.: Excavations at "The citz and the famous fortress of Kandahar, the foremost place in all of Asia". British Museum Occasional Papers 1981.
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32. Nissen, H.J.: Linking distant areas archaeologically. In: First International Conference on Pakistan Archaeology. Peshawar 1982.
33. Vidale, M.: Cultural Connections between the Hilmand Civilization and the Indus Plains. In: First International Conference on Pakistan Archaeology. Peshawar 1982.
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Translation by Dr.M.Mulloy

Fig.1 Archaeological map of Iranian and Afghan Sistan around the Hilmend-delta and the great lake "Hamun-i Sistan".

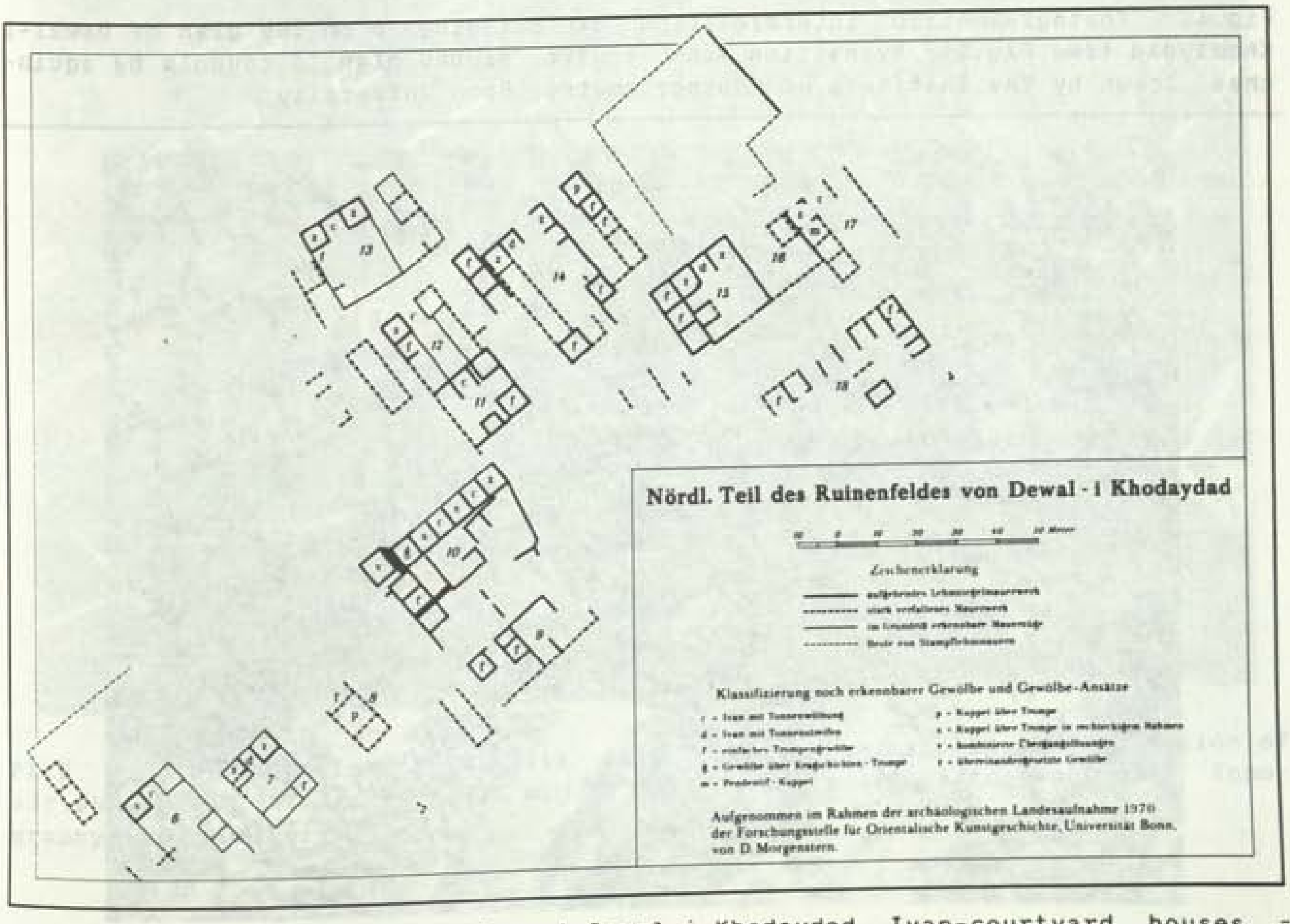


Fig.2 Ruins of the open settlement Dewal-i Khodaydad. Ivan-courtyard houses = Nr.6, 7, 12, 13, 14, 15; multi-towered construction = Nr. 10; cistern = Nr.8. Drawn by the Institute of Cartography and Topography, Bonn University

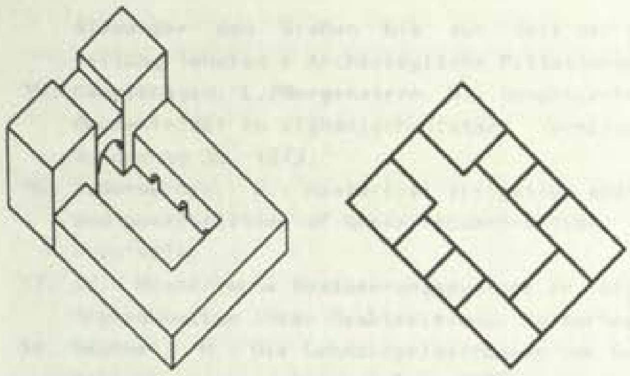


Fig.3 System of double-towered Ivan-courtyard house. Drawn by Prof. Klinkott. See also photograph Pl.4.

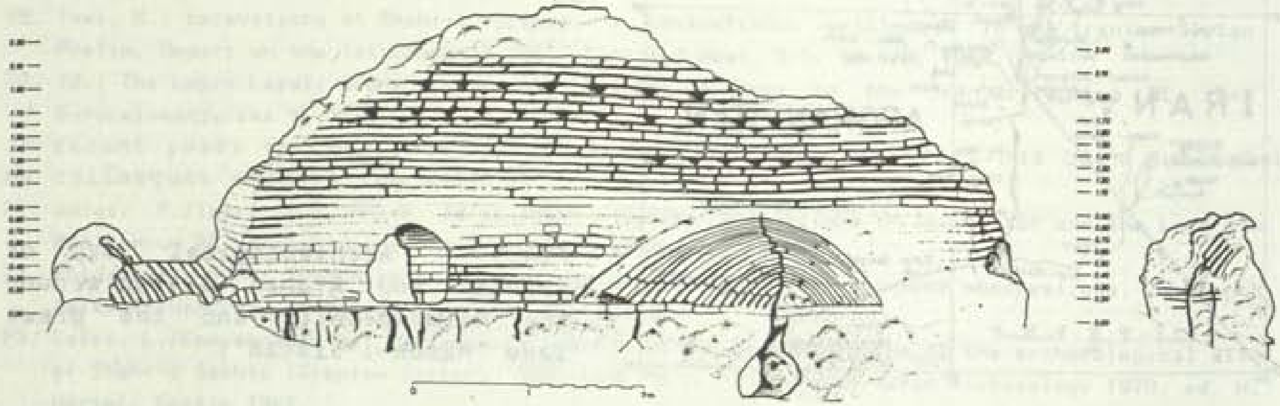
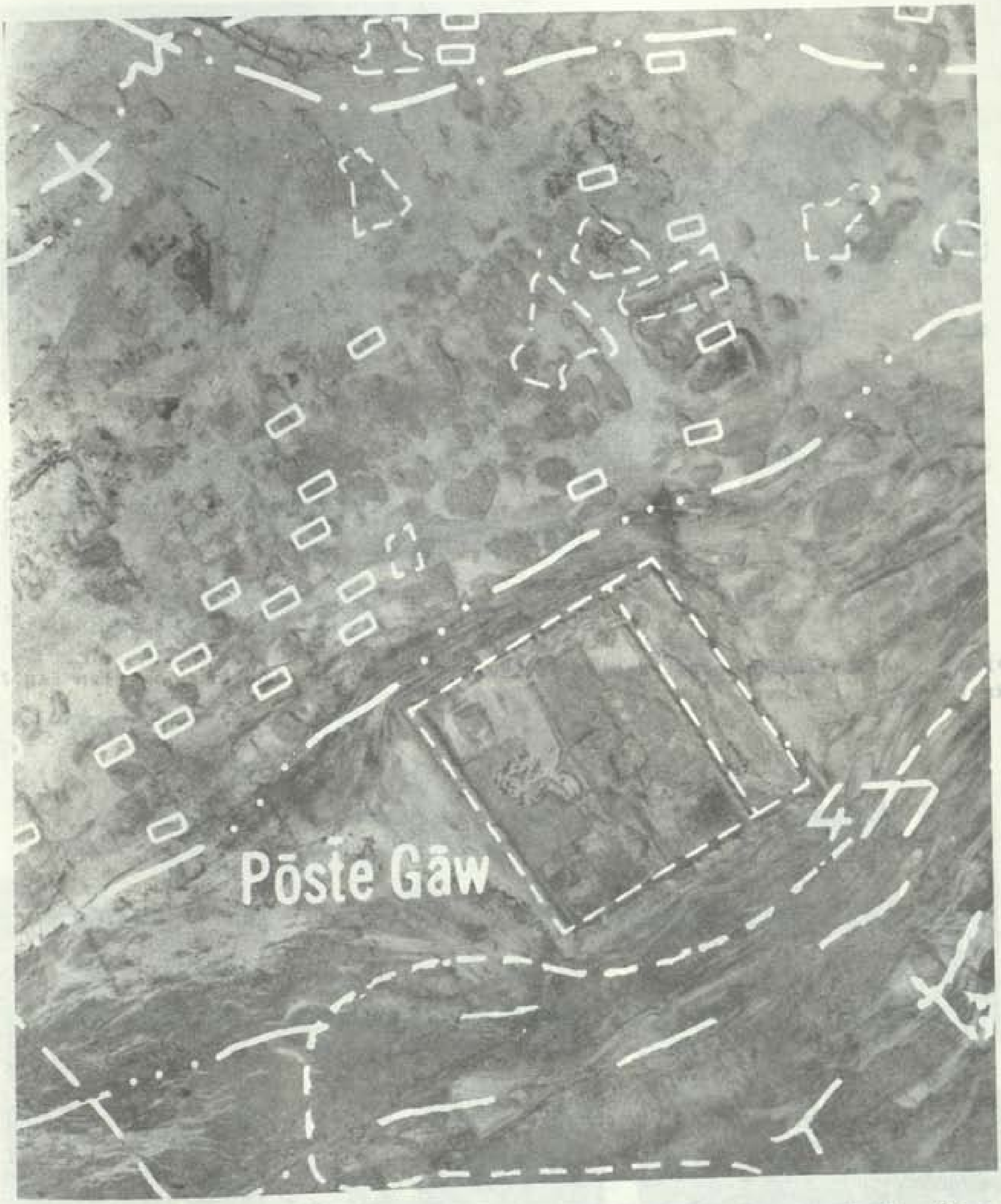


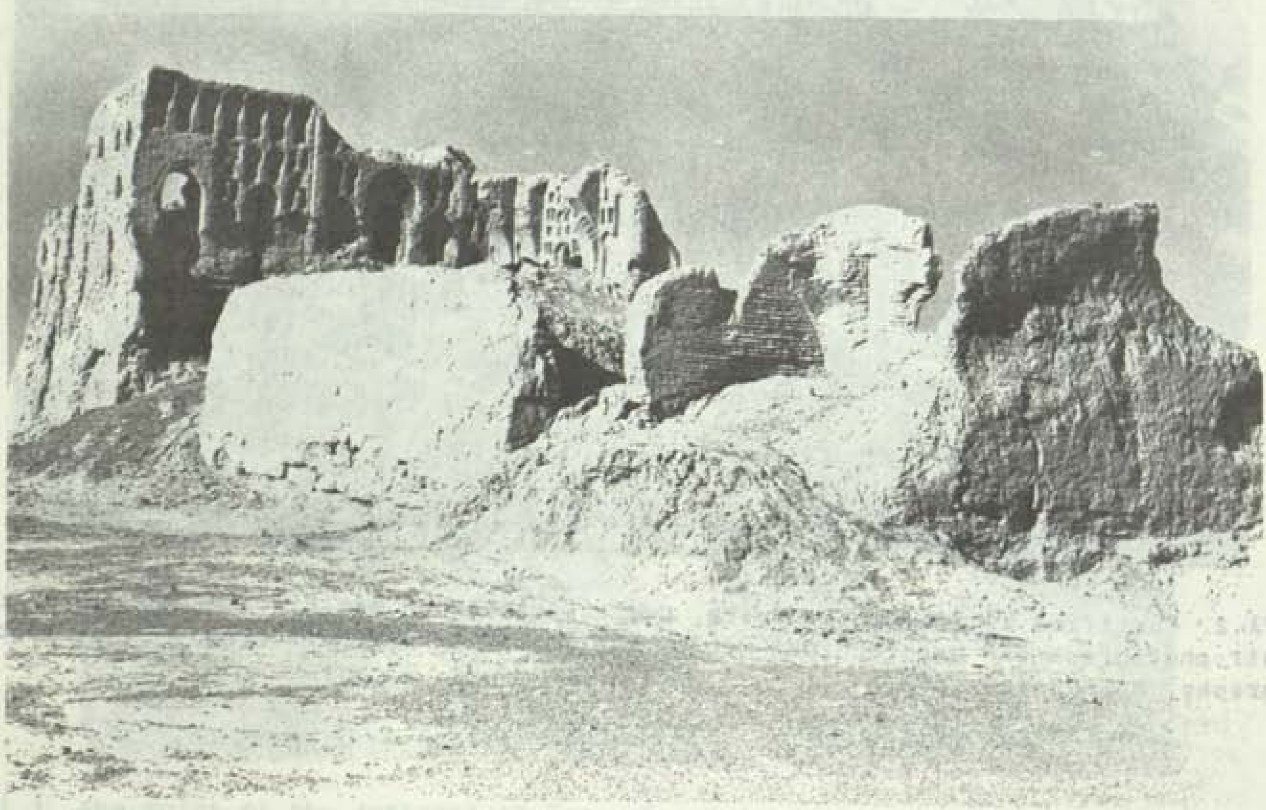
Fig.4 Photogrammetric interpretation of building 8 on the plan of Dewal-i Khodaydad (see Fig.2): transition from square ground plan to coupola by squinches. Drawn by the Institute of Photogrammetry, Bonn University

Pl.1 The ruins of the fortress of Tar-o Sar (also known as Shahr-i Gholghola and Taq), partly covered by moving sand dunes. Location on map Fig.1. Enlargement after air-photograph, Ministry of Mines, Kabul.



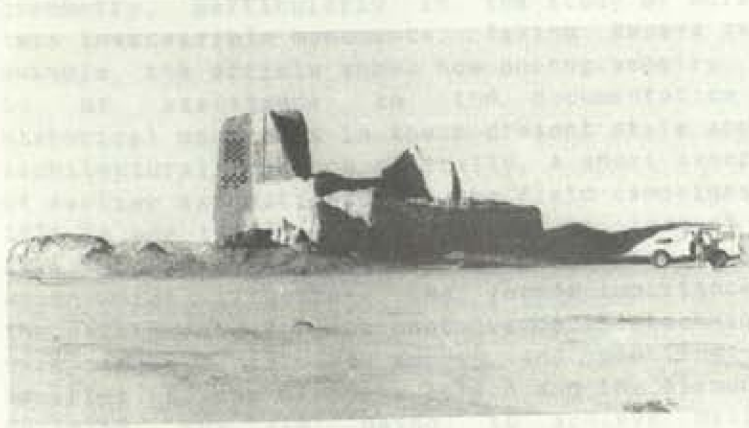
Pl.2 Fortified settlement of Poste Gaw. Location on map Fig.1. Combination of air-photograph and geographical map by the Institute of Cartography and Topography, Bonn University.

Pl.3 Multi-towered construction at Dewal-i Khodaydad. Location on plan Fig.2: Nr.10. Photo Fischer.

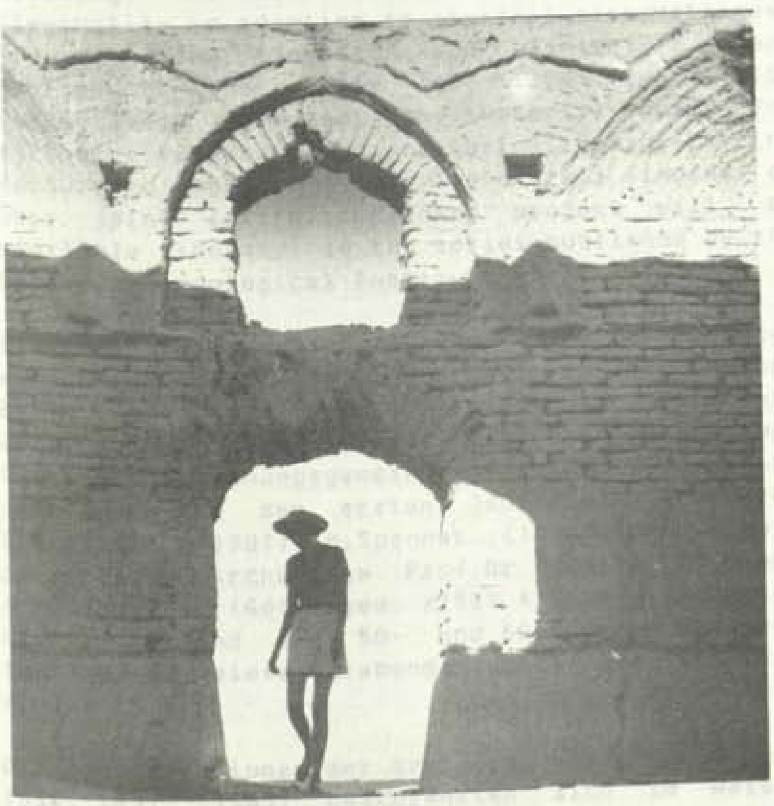


Pl.4 Abandoned, double-towered Ivan-courtyard house in the ruin field of Cegini. Location on map Fig.1; systematic interpretation in Fig.3. Photo Fischer.

Pl.5 Ruins of mud-brick Ivan-courtyard house near Dewal-i Khodaydad. Photo Fischer.



Pl.6 Ruins of a wind-mill near Gol-i Safed. Photo Thewalt.



Pl.7 Gol-i Safed. Interior of mud-brick Ziyarat (Reuther 1973: Pl.59,2 = building Nr.13), transformation of square ground plan by squinches and pendentives into circles as basis of dome (Reuther 1973; p.260-261). Photo Thewalt.

Pl.8 Gol-i Safed. Locating Ivan-courtyard houses on the archaeological map. Photo Thewalt.

Pl.3 Multi-towered construction at Dewal-i Khodaydad. Location on plan Fig.2: Nr.10. Photo Fischer.

Pl.4 Abandoned, double-towered Ivan-courtyard house in the ruin field of Cegini. Location on map Fig.1; systematic interpretation in Fig.3. Photo Fischer.

Pl.5 Ruins of mud-brick Ivan-courtyard house near Dewal-i Khodaydad. Photo Fischer.

Pl.6 Ruins of a wind-mill near Gol-i Safed. Photo Thewalt.

Pl.7 Gol-i Safed. Interior of mud-brick Ziyarat (Reuther 1973: Pl.59,2 = building Nr.13), transformation of square ground plan by squinches and pendentives into circles as basis of dome (Reuther 1973; p.260-261). Photo Thewalt.

Pl.8 Gol-i Safed. Locating Ivan-courtyard houses on the archaeological map. Photo Thewalt.

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ARCHITEKTUR-PHOTOGRAMMETRISCHE AUFNAHMEN UND AUSWERTUNGEN VOM SPÄTANTIKEN RESAFA/SYRIEN

THE PHOTOGRAMMETRIC SURVEY AND PLOTTING OF EARLY BYZANTINE ARCHITECTURAL REMAINS IN RESAFA/SYRIA

SUMMARY

Architectural historians and archaeologists are making increasing use of terrestrial photogrammetry, particularly in the study of more or less inaccessible monuments. Taking Resafa as an example, the article shows how photogrammetry can be of assistance in the documentation of historical monuments in their present state and in architectural research generally. A short synopsis of earlier expeditions and the field campaigns of 1976-78 and 1980 is followed by an account of Resafa's turbulent history and geographical situation which illustrate the former importance of the settlement. Various photogrammetric techniques were applied in the survey and plotting of Basilica A, the bishop's palace and the Alamundir building, the aim being to achieve maximum flexibility in adapting to physical circumstances. The resulting elevation and planimetric plans drafted to the scale of 1:50 and 1:100 respectively represent the material basis for further research on historically interesting features of the remains. The overall findings of this joint interdisciplinary project will be available shortly in the series published by the German Archaeological Institute (DAI) Berlin.

Die archäologischen Forschungen in der frühbyzantinischen Ruinenstadt Resafa wurden als interdisziplinäre Zusammenarbeit unter der Leitung des Priv.-Doz. Dr.Th.Ulbert von der Zentraldirektion des Deutschen Archäologischen Instituts (DAI) in Berlin im Jahre 1976 wieder aufgenommen. Das Unternehmen wird von der Deutschen Forschungsgemeinschaft (DFG) gefördert. Nach frühen Forschungsexpeditionen in den ersten Jahrzehnten des 20.Jahrhunderts durch F.Sarre und E.Hertzfeld (1907), H.Spanner (1918) und A.Musil (1928) hatte der Freiburger christliche Archäologe Prof.Dr.J.Kollwitz, angeregt durch seinen Kollegen A.M.Schneider (Göttingen, +1952 Aleppo), mit intensiven Grundlagenforschungen in Resafa während der 50- und 60er Jahre begonnen. Durch Kollwitz' Tod im Jahre 1968 wurden diese Grabungsstudien jäh unterbrochen (siehe Karnapp 1976 und Ulbert 1976).

Die Dokumentationen der Grabungen unter der Leitung von J. Kollwitz (s. Kollwitz 1954, 1957, 1963) beschränkten sich im wesentlichen auf die relativ gut erhaltenen Hauptbauten, die sog. Basilika B und den sog. Zentralbau, die freigelegt und von Architekten und Bauhistorikern nach Grund- und teilweise Aufriß händisch aufgemessen wurden (herkömmliche bzw. klassische Methode, (s. Mauelshagen et al. 1973). Außerdem wurde die Stadtmauer mit ihren vier monumentalen Toren, ihren 50 Wehrtürmen und ihren Wehrgängen in ihrer Gesamtheit von W.Karnapp (s. Karnapp 1976) aufgenommen und z.T. rekonstruiert.

Während der Arbeitskampagnen in den Jahren 1976-1978 und 1980 wurden die folgenden Ziele verfolgt: Innerhalb und außerhalb des Stadtbereichs wurde eine archäologisch-topographische Dokumentation im Maßstab 1:1.000 durchgeführt (H.Tremel, Deutsches Geodätisches Forschungsinstitut München). Die sog. Basilika A (oder auch Sergios-Basilika) mit Bischofskapelle und der Alamundirbau (Abb.1-5) ließen sich mit Hilfe der terrestrischen Photogrammetrie (TAF-Ausrüstung, Wild P32, Zeiss SMK120, Hasselblad 500C/M) in ihrem derzeitigen Bauzustand nach Aufriß und teilweise Grundriß erfassen (A.Grün, L.Mauelshagen 1978). Die Stereomeßbilder wurden am Lehrstuhl für Photogrammetrie der Technischen Universität München und am Institut für Photogrammetrie der Universität Bonn graphisch und teilweise mittels der Orthophoto-Technik ausgewertet. Eine vermessungstechnisch sowie photogrammetrisch unterstützte Überwachung der Grabung half außerdem die Befunde sichern.

GEOGRAPHIE UND GESCHICHTE

Die Ruinenstadt Resafa (ca.400mx600m) liegt ca.35km vom Euphrat entfernt am nördlichen Rand der syrischen, hier flach gewellten Wüstensteppe mit semi-aridem Klima und ist, von der neuen Autostraße Aleppo-Raqqa kommend, heute über eine asphaltierte Piste, die in Hammam (ca.150km von Aleppo) nach Süden abzweigt, bequem zu erreichen (Abb.6). Ihre wechselvolle Geschichte ist wesentlich durch ihre geographische Lage bestimmt worden.

In diesem Landstrich liefen bereits im Altertum wichtige Handelsstraßen aus Ägypten, Arabien, Mesopotamien und Kleinasien zusammen, wodurch ein reger kultureller Austausch gefördert wurde. Schon in den aus dem 9.vorchristlichen Jahrhundert stammenden assyrischen Keilschriften und in der Bibel (Jesaja 37,12 = Könige 19,12) ist Resafa benannt (Karnapp 1976 u. Ulbert 1976).

Die Karawanenstraße von Assur über Zenobia, Resafa, Palmyra und Damaskus zum Golf von Akaba kristallisiert sich schon sehr früh, wie z.B. der Franzose A.Poidebard (Poidebard 1934) anhand von Luftbildern aus den Jahren um 1930 darlegt (Abb.7), als eine Hauptverkehrsroute heraus, deren Bedeutung in römischer und spätantiker Zeit nicht nachläßt. Resafa ist einer der wichtigsten Kontrollplätze für Handel und Verkehr.

Als sog. Strada Diocletiana wird diese Straße an der Wende vom 3. zum 4.Jahrhundert n.Chr. ausgebaut und durch Kastelle befestigt und sichert so als Limes Arabicus das römische Imperium gegen Parther und Sassaniden.
Als im Jahre 250 n.Ch. ein Soldat der Kastellbesatzung namens Sergios während der letzten Christenverfolgung unter Diocletian das Martyrium erleidet und vor den Toren des Kastells beigesetzt wird, schließt sich bald für die folgenden Jahrhunderte eine zunehmende Verehrung des Soldatenheiligen und eine starke Pilgerbewegung an. Die heute noch aufragenden Ruinen der nun bis ins 8.Jahrhundert "Sergiopolis" genannten Stadt, die unter der Herrschaft Kaiser Justinians (527-565) zum Schutz gegen die Sarazenen und Perser eine neue Stadtmauer erhält, stammen aus dem 5. und 6.Jahrhundert. Seit der ersten Hälfte des 5.Jahrhunderts ist die Stadt Bischofssitz (s. Karnapp 1976).

Gemäß der Gründungsinschrift, die im Jahre 1976 im Apsisfußboden auf einer Marmorplatte in situ neu entdeckt wurde, ist die sog. Basilika A vom damaligen Bischof Abraamios im Jahre 559 dem heiligen Kreuz geweiht worden. Eine derartige Dedikation war für diese Zeit recht selten und hatte keinen Einfluß auf die bauliche Grundrißgestaltung der Kirche (Ulbert 1979 u. 1977).

Nach der Eroberung durch den Islam im Jahre 636 gibt es ein friedliches Nebeneinander von Christentum und Islam.

Durch ein Erdbeben im ausgehenden 8.Jahrhundert werden große Teile der Stadt und ihrer Kultbauten zerstört. Der christliche Sergioskult lebt fort bis ins 11.Jahrhundert, in dem sich weitere Erdbeben ereignen. Das damalige Bemühen um die bauliche Erhaltung und Restaurierung der Basilika kann am heutigen Baubestand abgelesen werden (Abb.8, 9).
Mit dem Jahre 1093 läßt sich der letzte Bischof nachweisen und mit dem Mongoleneinfall im Jahre 1247 verliert Resafa seine Bedeutung und wird aus Furcht in den folgenden Jahren verlassen (Karnapp 1976 u. Ulbert 1976).

Resafa wurde aus reinem Gipsgestein erbaut, das aus den antiken Steinbrüchen der Umgebung gewonnen wurde. Seit dem Ende des 13.Jahrhunderts sind die Reste dieser bedeutenden Stadt den Witterungseinflüssen des rauhen Wüstensteppenklimas preisgegeben und stellen heute die syrische Antikenverwaltung vor schwierige Restaurierungs- und Konservierungsprobleme.

PHOTOGRAMMETRISCHE ARBEITEN DER KAMPAGNEN

Die photogrammetrischen Arbeiten stellen einen wesentlichen Mosaikstein zur Erforschung und Analyse der hier gegebenen bauhistorischen Hintergründe dar. Sie liefern in den Meßbildern und in Form von Plänen im Maßstab 1:50 von der noch vorhandenen Bausubstanz ein bedeutendes Zeitdokument, dessen Archivierung von historischem Interesse ist. Hier konnten die Basilika A nebst Bischofspalast und der Alamundirbau (Abb.1-5, 8), eine Audienzhalle des Ghassanidenfürsten Alamundir, die nördlich vor der Stadt gelegen ist und deren kleine Kreiskuppeln und Längstonnen noch teilweise erhalten sind, erfaßt werden.
Die Komplexität und der Detailreichtum der Bauformen ließen die Photogrammetrie in den Vordergrund rücken. Die klassische Handaufmessung der Bausubstanz war aussichtslos (vgl. auch Mauelshagen et al. 1973), zumal das stark verwitterte Gipsgestein bei direkter Berührung ein hohes Sicherheitsrisiko darstellte.

Daneben wurde eine Grundrißvermessung des Gesamtbezirks der Basilika A durchgeführt (dies z.T. photogrammetrisch und durch Handaufmessung). Desweiteren waren die laufenden archäologischen Grabungen vermessungstechnisch und photogrammetrisch zu dokumentieren.
Die Basilika A, die im Südosten der Stadt gelegen ist, ist ein ausgedehnter Baukomplex, dessen Zentrum eine dreischiffige Basilika von 28m Breite und 55m Länge bildet (Abb.9). Das Mittelschiff wird durch zwei Pfeilerpaare in drei Abschnitte gegliedert und enthält das für Syrien typische Bema. Das Halbrund der Apsis besitzt eine umlaufende Klerusbank.
Die aufgrund der Erdbeben notwendig gewordene Stützung der Mittelschiffwände der Basilika durch kleinere Arkaden, die durch zusätzliche Säulen getragen werden, durch Füllmauerwerk und schließlich durch mächtige Stützmassive von außen, ist in den Abb. 8 und 9 zu erkennen. Im Nordhof der Basilika war schon recht früh eine Moschee eingerichtet.

Zum Teil rufen die bis 16m hoch aufragenden Mauern bei Aufnahmeentfernungen von oft nur 4m schwierige Aufnahmebedingungen hervor. Aus Flexibilitätsgründen und um die Effizienz der Arbeiten zu gewährleisten wurden unterschiedliche Kammern verwendet:
- Phototheodolit TAF ("Terrestrische Ausrüstung Finsterwalder"), c=160mm, $13x18cm^2$
- Meßkammer Wild P32 (c=64mm, $6x9cm^2$, mit 18 Reseaukreuzen, Verwendung von handelsüblichem Rollfilm möglich)
- Stereomeßkammer Zeiss SMK120 (c=60mm, $9x12cm^2$)
- Hasselblad 500C/M (Objektiv Distagon, f=40mm, $6x6cm^2$).

Als Auswertegeräte waren verfügbar:
- Stereoplanigraph C8
- Stereoautograph 1318
- Analytisches Auswertesystem Planicomp C100

- Entzerrungsgeräte SEG I und V
- Digitaler Orthoprojektor Wild OR-1 Avioplan

Somit konnte praktisch der gesamte Bereich terrestrisch-photogrammetrischer Aufnahme- und Auswerteverfahren abgedeckt werden: Einzelaufnahmen zur Entzerrung, orientierte und nichtorientierte Stereoaufnahmen zur Strichlinienauswertung bzw. Orthophotos, Einsatz von Meßkammern und Nichtmeßkammer (Hasselblad).
Extreme Lichtverhältnisse erforderten eine ausgewogene Terminierung der Belichtungszeitpunkte. Um den Erfolg der Aufnahmen zu sichern, wurde im Schafstall der gastgebenden Beduinen ein provisorisches Photolabor eingerichtet und die Platten/Filme unmittelbar vor Ort, allerdings unter primitivsten Bedingungen, entwickelt.

Während der Herbstkampagne 1976 wurde im Bereich der Basilika A ein lokales Polygonnetz angelegt, zusammen mit einem Gerüst von dauerhaft markierten Paßpunkten, welches im wesentlichen Bauachsen des Objektes erfaßt und den Rahmen für die lage- und höhenmäßige Einpassung der photogrammetrischen Aufnahmen darstellt. Die Anordnung der Paßpunkte wurde so getroffen, daß sie einen Anschluß der im folgenden Jahr 1977 durchgeführten geschlossenen Grundrißvermessung ermöglichte. Somit bildet das Netz der geodätischen Polygonpunkte und der photogrammetrischen Paßpunkte den Rahmen für die Grundrißvermessung.
Außerdem wurden Beobachtungen im Objektraum (z.B. nivellierte Punkte und Strecken, vertikale Strecken etc.) als Modell-Einpaßinformation genutzt (vgl. hierzu Wester-Ebbinghaus 1981).

Die photogrammetrischen Aufnahmen repräsentieren ein bestimmtes Ordnungsprinzip. So wurde überall dort, wo eine ausreichende Aufnahmeentfernung realisiert werden konnte (maximal genutzte Distanz ca.80m), mit der großformatigen TAF gearbeitet. Dies gilt für die Aufnahme der Außenfassaden sowie für die Schmalseiten der Haupt- und Nebenschiffe (u.a. Hauptapsis). Bestens bewährt hat sich dabei wieder einmal die Einrichtung des höhenmäßig verschiebbaren Objektives zur optimalen Erfassung von Objektteilen. Eine exakt senkrechte Orientierung der Aufnahmeachse des linken Standpunktes zur Fassadenebene ist für die Auswertung der TAF-Aufnahmen am Stereoautograph 1318 geradezu notwendig, da sich dort das Gerätemodellsystem nach eben dieser Aufnahmeachse richtet. Steht bei einer Meßkammer ein horizontaler Teilkreis zur Verfügung (TAF, P32), so läßt sich die Orientierung der Aufnahmeachse nach einem einfachen Verfahren rasch und genau erreichen.

Das Netz der TAF-Stereoaufnahmen wurde dort durch SMK-Photos verdichtet und ergänzt, wo vorstehendes Mauerwerk keinen Einblick in die Bezugsfassade erlaubte. Daneben wurden die Innenaufnahmen, d.h. die Aufnahmen der inneren Längsfassaden im Bereich des Hauptschiffs (Aufnahmedistanz ca.12m) und des nördlichen und südlichen Seitenschiffs (Aufnahmedistanz ca.7m) sowie im Innenbereich der "Bischofskapelle" fast ausschließlich mit der SMK erstellt. Dabei ließen sich einige um 30° geneigte Aufnahmen nicht vermeiden. Um die Orientierung am Stereoplanigraphen C8 zu erleichtern, wurde mit den unzureichenden Hilfsmitteln, die das SMK-System bietet, versucht, die Aufnahmen in der Regel so zu konzipieren, daß die Aufnahmeachsen senkrecht zur Fassadenebene verliefen. SMK- und PK32-Aufnahmen wurden durch Vergrößerung am SEG V auf den für die Auswertung am Stereoplanigraphen C8 notwendigen Kammerkonstantenbereich gebracht.
Vor allem innerhalb der "Bischofskapelle", wo z.T. nur Aufnahmedistanzen von ca.3m gegeben waren, kam die Hasselblad mit WW-Objektiv zur Anwendung. Dabei wurden vorwiegend Einzelaufnahmen zur Entzerrung, aber auch nichtorientierte Stereoaufnahmen zur Strichlinienauswertung gefertigt. In erster Linie dienten die Hasselbladaufnahmen zur Ergänzung von Lücken in Plänen, die über SMK- bzw.

TAF-Aufnahmen hergestellt wurden.
Die P32 wurde vor allem in den engen Räumen des Alamundirbaus und für Spezialzwecke eingesetzt, so z.B. zur Aufnahme verschiedener Grabungszustände des freigelegten Fußbodens im östlichen Vorraum des nördlichen Seitenschiffs (NOS, Abb.9, 10) und zu Fußbodenaufnahmen in der "Bischofskapelle" (BK). Hierbei mußte von erhöhten Standpunkten mit Freihandaufnahmen (vergleichbar dem Konzept der Luftbildphotogrammetrie für Aufnahme und Auswertung) gearbeitet werden. Jeweils fünf am Boden ausgelegte und über Streckenmessung und Nivellement lokal bestimmte Paßpunktmarken dienten zur Orientierung. Zur Auswertung dieser Aufnahmen hat sich das Analytische Stereoauswertesystem Planicomp C100 bewährt. Es können einerseits von der Aufnahme her allgemeinere Konzepte realisiert werden (Kammerkonstantenbereich, nichtorientierte Meßaufnahmen, Freihandaufnahmen, Amateuraufnahmen etc.), andererseits aber auch die Auswertung entscheidend beschleunigt und verbessert werden (Orientierung, automatisches Punktanfahren etc.). Sehr praktikabel für diesen Auswertetypus sind auch einige Routinen zum automatischen Zeichnen, wie Kreis- und Kurvenzeichnen, Gitternetzauftragen, Beschriften.

Ein weiterer erfolgreicher Versuch im Hinblick auf die Verwendung neuer Technologien wurde mit dem Digitalen Orthoprojektor Wild OR-1 Avioplan unternommen. Abb.11 zeigt eine Meßaufnahme (TAF) der Wand der Hauptapsis (HA). Die Apsiswand bildet einen Zylinderausschnitt, dem beim Übergang zur Decke (jetzt nur noch teilweise erhalten) ein Kugelviertel aufgesetzt ist. Somit zeigen die horizontalen Linien der Apsiswand bei Zentralprojektion eine deutliche Krümmung. Durch die Orthoprojektion wird diese Krümmung rückgängig gemacht, und es entsteht ein in allen Teilen maßstabsgerechter Aufrißplan, der erdbebenbedingte Deformationen erkennen läßt. Dem Benutzer (Archäologe, Bauhistoriker etc.) steht der volle Informationsgehalt und -umfang der entzerrten photographischen Aufnahme zur Verfügung. Abb.12 zeigt das Orthophoto, welches dankenswerterweise von der Firma Wild/Heerbrugg hergestellt wurde. In Abb.13 ist die Auswertung des Fußbodens der Hauptapsis dargestellt.
Die Abwicklung des Projektes Resafa zeigt eine sehr wirkungsvolle interdisziplinäre Zusammenarbeit (Frühchristliche Archäologie, Islamistik, Kunstgeschichte, Vermessungswesen, Photogrammetrie, Mineralogie), bei der ein effizientes Arbeiten, auch dank guter Kooperation, ermöglicht wurde.

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Zusammenfassung aus dem Deutschen übersetzt von Dr.M.Mulloy

Abb.1 SMK-Meßbild: Teil der inneren südl. Längsfassade des Basilika-Hauptschiffes

Abb.2 SMK-Meßbild: Kapelle des Bischofssitzes

Abb.3 P32-Meßbild: Rundkuppel im Alamundirbau

Abb.4 Meßbild-P32: Teil einer Längstonne im Alamundirbau

Abb.5 Meßbild-P32: Teil einer westlichen Innenwand im Alamundirbau

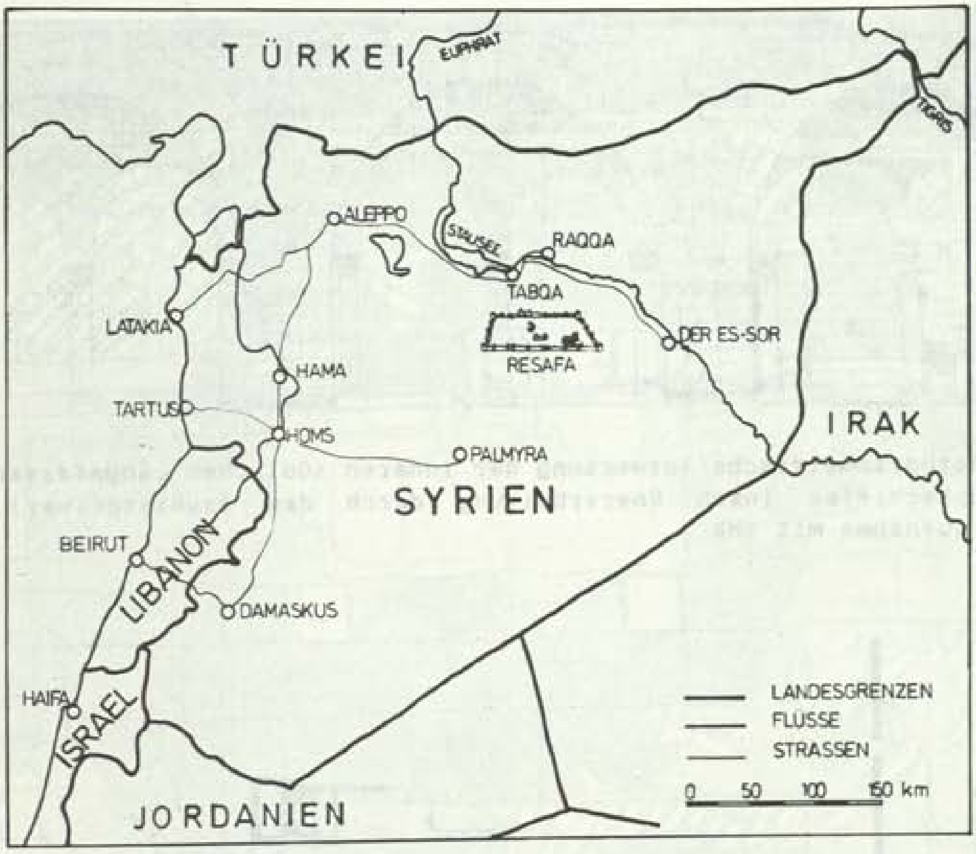

Abb.6 Die Lage Resafas (nach Ulbert 1979)

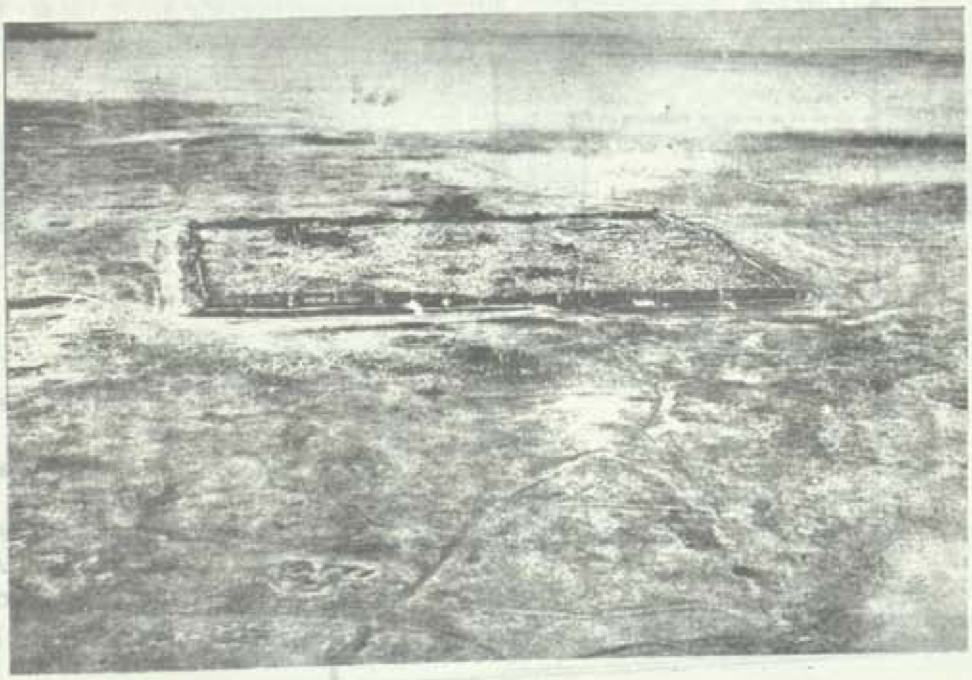

Abb.7 Luftbild von Resafa aus nörlicher Richtung (nach Poidebard 1934)

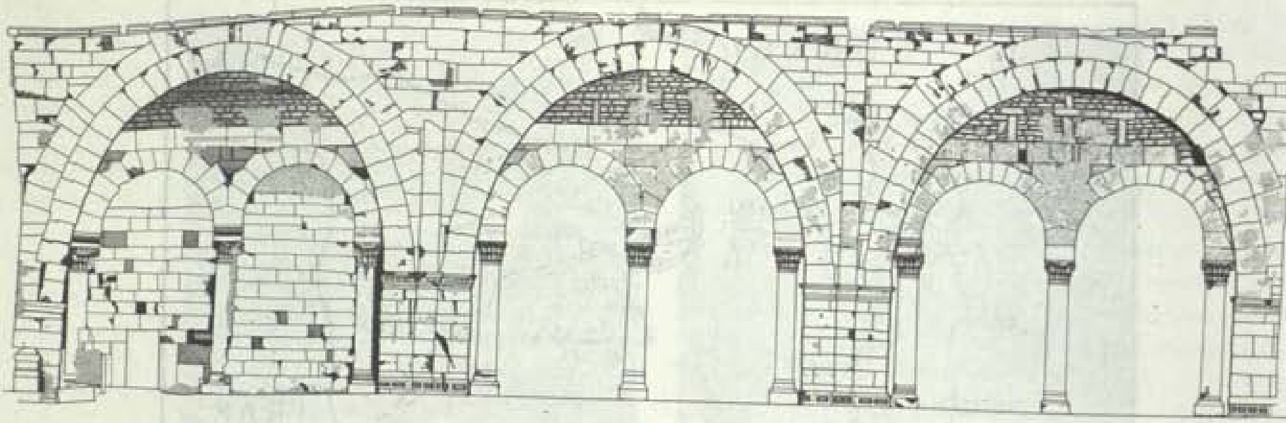

Abb.8 Photogrammetrische Auswertung der inneren südlichen Längsfassade des Basilika-Hauptschiffes (nach Überarbeitung durch den Bauhistoriker), Maßstab ca.1:150, Aufnahme mit SMK

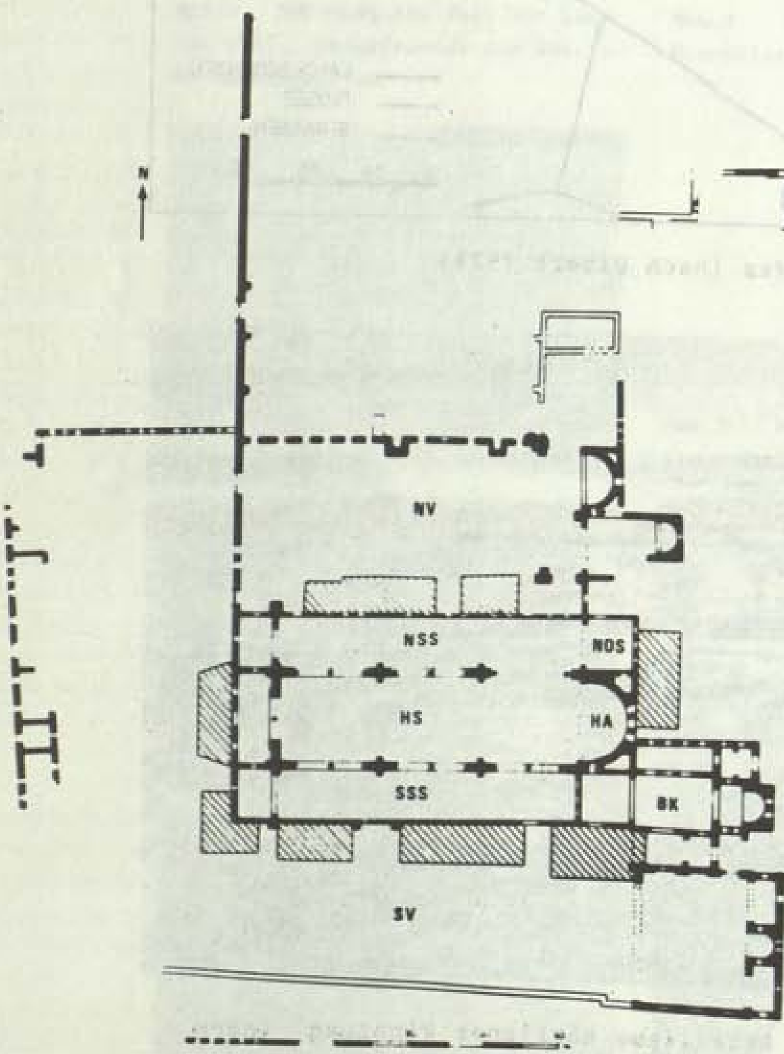

Abb.9 Grundriß der Basilika A

BK... "Bischofskapelle"
HA... Hauptapsis
HS... Hauptschiff
OS.. Östlicher Vorraum des nördlichen Seitenschiffs
NSS.. Nördliches Seitenschiff
NV... Nördlicher Vorhof
SSS.. Südliches Seitenschiff
SV... Südlicher Vorhof
Nach Kollwitz

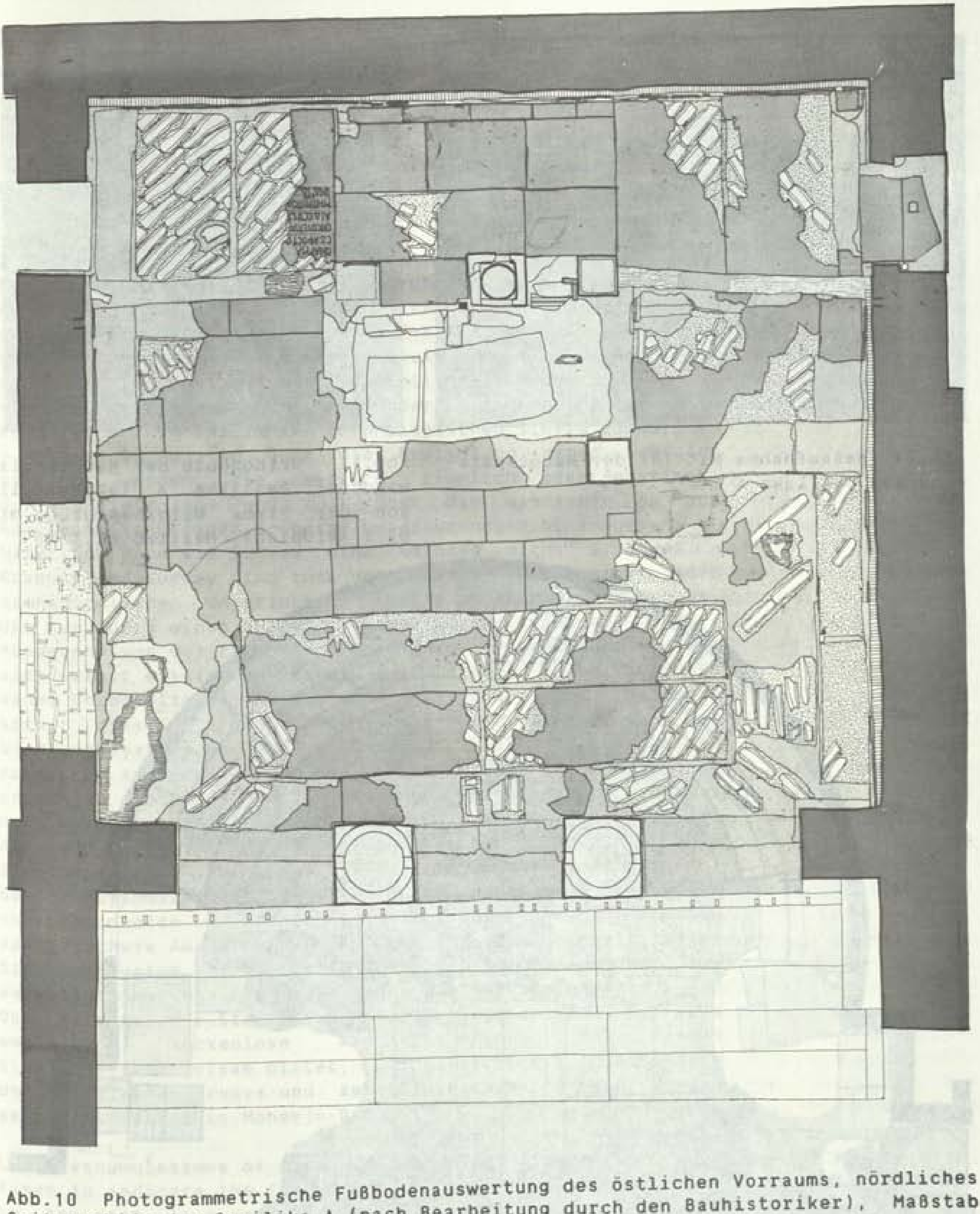

Abb.10 Photogrammetrische Fußbodenauswertung des östlichen Vorraums, nördliches Seitenschiff der Basilika A (nach Bearbeitung durch den Bauhistoriker). Maßstab ca.1:50, Aufnahme mit Wild P32

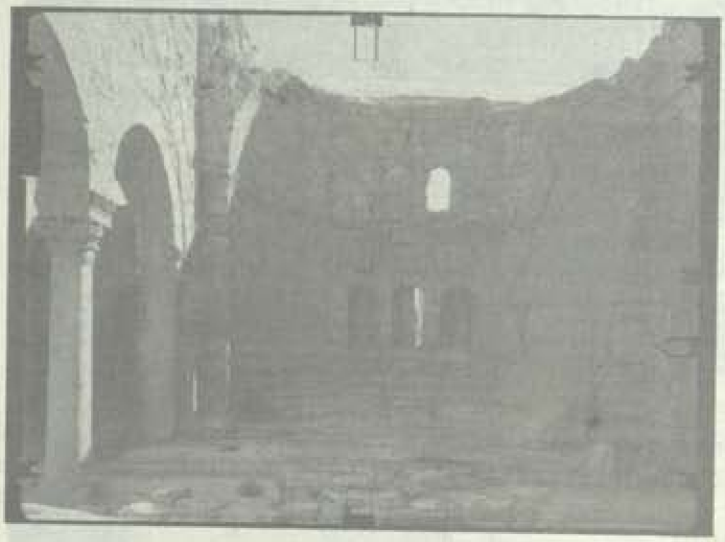

Abb.11 Meßaufnahme mit TAF der Hauptapsiswand der Basilika A

Abb.12 Orthophoto der Hauptapsiswand der Basilika A (hergestellt von der Firma Wild/Heerbrugg mit OR-1 Avioplan), Maßstab ca.1:60

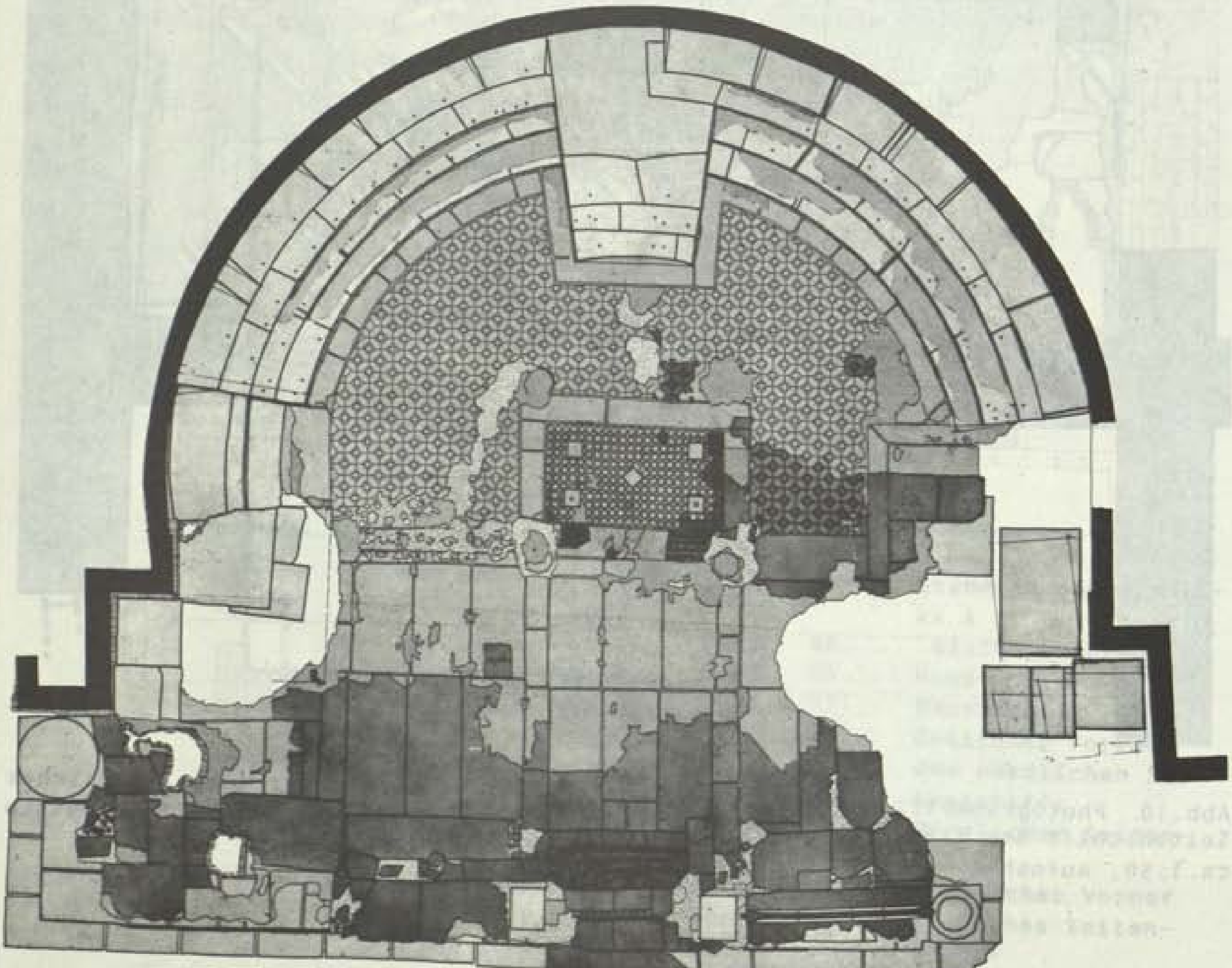

Abb.13 Photogrammetrische Fußbodenauswertung der Hauptapsis der Basilika A (nach Überarbeitung durch den Bauhistoriker), Maßstab ca.1:75, Aufnahme mit TAF

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THE EVIDENCE OF ARCHAEOLOGICAL SURVEYS

DIE AUSSAGEKRAFT ARCHÄOLOGISCHER SURVEYS

ZUSAMMENFASSUNG

Der Fortschritt in seiner Durchführung und Auswertung ließ den archäologischen Oberflächensurvey zu einem eigenen Zweig der Archäologie werden; ohne die Hilfe einer Ausgrabung an einem Siedlungsort können heute mit verfeinerten quantitativen Methoden und kontrollierter Probenahme anhand von Oberflächenfunden - insbesondere durch die Möglichkeit, Keramikscherben bestimmten chronologischen Stufen zuzuordnen - gewisse Grunddaten über die Besiedlung eines Gebietes erbracht werden, die zeitlich, räumlich oder funktional differenziert sind und weit über die einfachen An- und Abwesenheitsaussagen früherer Untersuchungen hinausgehen. Natürlich kann ein Survey eine Grabung nicht ersetzen - Grabung und Survey sind zwei untrennbare Aspekte einer jeder archäologischen Untersuchung -, es gibt aber Grundaussagen, die nur durch einen Survey gewonnen werden können. Ausgehend von der Erkenntnis, daß keine größere Siedlung aus sich selbst existieren kann, sondern stets den Mittelpunkt eines Unterhaltungs- bzw. Siedlungssystems bildet, beziehen sich diese Grundaussagen auf die Datierung der Siedlungssysteme und auf die Regeln, nach denen sich die räumliche Anordnung sowie die verschiedenen Siedlungsgrößen innerhalb dieser räumlichen Anordnung gestalten und die Teil des Wesens der betreffenden Kultur sind, d.h. genauer, Aussagen über die hierarchische Struktur der Siedlungssysteme (ein- oder mehrschichtige Systeme und der damit zusammenhängenden Anzahl von Zentren und Siedlungen untergeordneten Ranges) und in einzelnen Fällen spezifischere Aussagen darüber, ob der Zusammenhalt eines Siedlungssystem eher auf wirtschaftlichen oder auf verwaltungsmäßigen bzw. politischen Interessen beruhte. Das Beispiel der Stadt Uruk im südirakischen Raum, die eine weitgehend lückenlose Wiederentdeckung der alten Siedlungsverhältnisse bietet, verdeutlicht die Arbeitsweise des Oberflächensurveys und zeigt gleichzeitig den Nutzen seines Einsatzes in Mohenjo-Daro.

Large accumulations of pot-sherds or other finds on the surface have always been taken to indicate the former presence of a settlement on the spot at some period in the past. As a result of our increased knowledge of archaeological contexts, especially in regard to the dating of pot-sherds by their appearance, it is possible to allocate such surface finds to particular chronological levels. Thus the fact that there must have been an ancient settlement on the spot can be expanded by the information when the settlement was inhabited. Without resorting to an excavation it is, therefore, still possible to obtain certain basic data on the settlement of an area. This procedure attracted growing attention from

the time archaeologists began to realise that no settlement, and certainly no larger one, could exist self-sufficiently but rather that each settlement represented the centre of a subsistence system or - on a higher level - a settlement system.

Meanwhile the execution and analysis of archaeological surveys has become a recognised branch of archaeology in its own right, with its own special rules which are being continually developed and refined. Whereas earlier archaeologists used to concentrate mainly on the gathering of finds which were characteristic of very specific periods and which thus allowed the settlement activity to be dated with some precision whilst ignoring the usually more numerous non-"diagnostic" finds, in recent years the use of quantitative methods or controlled sample-taking has led to a vast improvement in the methods of gathering and interpreting such material. Consequently, it became possible to make distinctions of time, space and function which far surpassed the mere confirmation of presence or absence which resulted from earlier investigations.

Today one of several working methods can be applied, depending on the object of the operation. The differences between them may lie in the thoroughness of the material collecting, the fineness of the recorded details or in the amount of time available for the collecting. Naturally no survey - no matter how intensively or carefully carried out - can substitute for an excavation; at the same time it is true that in certain cases even the most hastily executed survey can yield information otherwise unobtainable. Both excavation and survey are two inseparable aspects of every archaeological investigation; in what follows I will concentrate on the type of information which can be gained through surveys alone.

Human geographers have long been familiar with the observation that settlements which are situated so closely together as to have allowed not merely trade connections but daily intercourse between them are not found scattered at random over a given area but are sited according to certain rules. These rules, affecting the spatial arrangement as a whole and also the various settlement sizes within this spatial arrangement, form part of the essence of the culture in question: if, for example, all the settlements in a culturally distinct area are of the same size, this indicates clearly that the fundamental patterns of this culture were not the same as they would have been had the settlements in this area varied greatly in size.

Where the settlements vary in size they are not scattered at random but tend rather to form groups of network patterns, the bigger settlements representing the knots.
Such concentrations of settlements seem to follow the same rules the world over with only minor concessions to local peculiarities. The principle would appear to be that smaller settlements grow up close enough around a larger urban centre to allow intensive daily contact between them of every kind depending on the prevailing transport conditions. The reason for this settlement pattern is to be sought in the rise of new services and functions - as a result of the increasing division of labour - catering to a larger catchment area than that of a single settlement, i.e. which provide for a number of settlements apart from the home one. The "central" functions become concentrated in a few places and primarily in a geographically central settlement. Insofar as this settlement did not already occupy a central position for other reasons, this is one way it could have attained central importance for the whole group. This importance tends to increase further through the continuing assimilation of additional central

services and functions by an already established nucleus.

The degree of differentiation within such settlement groups shows clearly that the society in question was acquainted with the phenomenon of rank, inequality of status and hierarchy. It can also be taken for granted that political decisions were taken in the larger central settlements, so that in the case of a settlement system comprising a nucleus surrounded by smaller units we may speak of varying levels of political decision-making.

Besides such two-level systems there are also multi-level systems. Here the levels of several two-level systems co-existing within a coherent area have interconnected as a result of central functions of predominant importance homing in on an already existing nucleus which is thus promoted to a centre on the next highest level. The economic, social and political structures can then undergo further specialisation, indicating the development of the culture concerned towards greater complexity. We may also assume that the third-level centres are naturally more powerful than those on a lower level, as the size of the area affected by the political decisions of such an upper-level centre is greater.

Although all this information has been gleaned from the study of modern settlement systems it has been proven to be universally valid, so that there is reason to suppose that settlement behaviour in the past was governed by these same rules. The precision with which the quality and quantity of the central functions or the extent of the interdependence among the individual settlements can be defined depends, of course, on the exactness of the information which can be obtained on the settlements themselves, their growth, personal traffic and trade connections. Here an absolute minimum of information regarding the size of the settlements and their spatial relationship to one another is necessary, apart from the certain knowledge that such settlements must have existed contemporaneously. Initially, only a few fundamental statements with no claim to further differentiation can be made with any confidence.

Certain conclusions can be drawn, for example, if the condition of contemporaneity of a number of older settlements is fulfilled, if it is apparent that they can be subdivided into three clearly separable groups according to size and that higher ranking settlements are surrounded by ones of the next lowest rank thus conveying the impression of a three-level system. Given these preconditions, we can state with some certainty that the culture in this area was more highly developed than that in an area where only two-level systems are testified, not to mention those areas which only show traces of settlements of approximately the same size without any recognisable systematic connection between them. As regards the nature of the central functions which served as interconnecting links, the internal cultural intercourse and exchange of ideas, the economic, political and social structures - the present state of our knowledge allows no more than speculation. Perhaps the only statement that can be made is that it would appear from the nature of inter-settlement relationships that the hierarchical principle in all these structures was very pronounced.

This basic information can lead to more specific conclusions on one point only. Before elaborating, however, I want to draw attention to a conventional method used by archaeologists to represent inter-settlement relationships graphically. This method is based on the premise that ideally the catchment area of a central settlement formed a ring around it and that several such central settlements with their respective catchment areas grew up over a level plain. Taking it as a

matter of principle that by definition catchment areas may not overlap, we find that tracts of land are left over between the contact points of the circles which do not belong to any centre. If we take as a second principle, however, that the available area should be divided up completely among the centres, the result is a slight modification of the hypothetical circle in the form of a concentric hexagon. This geometric shape represents a model cluster of settlement systems which covers the entire area under investigation and which can be expanded in every direction. Ideally, the smaller settlements dependent on the centre dot the relevant hexagon. Here it is possible to draw certain distinctions based on the position of the settlements - some will coincide with the angles, some with the centres of the lines and others will fall somewhere between the lines and the centre. The differences in constellation would appear to reflect differences in the relationship between centre and hinterland.

The settlement systems vary in spatial form depending on their primary, central functions in their urban centres. A series of three abstract models of settlement system types can be constructed on the premise that the connecting links between the systems are represented primarily by a common administration or mutual economic interests, such as the marketing of agricultural produce or the distribution of centrally stored goods. Following the "inventor" of the settlement centre theory, W. Christaller, these models are labelled K3, K4 and K7 (Fig.1). The theory behind them is that it is an advantage for a settlement to have equal access to as many urban centres (= markets) as possible, so that any price differences between them can be exploited to get the best prices possible for the home produce. As can be seen, the organisation form represented by the K3 model enables each settlement to have equally good access to three market centres.

A cost factor to be reckoned with in the distribution of goods from a centre is transport; costs are low if distances are short. Settlements sited according to this principle lie half-way on the direct routes between pairs of urban centres. The inhabitants accept the fact of now being able to choose between the goods on offer in two centres only in exchange for the advantage of low transport costs - K4.

Whereas these two model forms of settlement organisation are constructed on economic principles, the K7 model is based on the theory that the individual settlements comprising a system are linked primarily by means of a central administration located in the urban centre. The advantages of the individual settlements maintaining contacts with several centres underlie the K3 and K4 models; in the case of the K7 model the contacts of a settlement are restricted to a single centre, as a settlement cannot be under the administrative jurisdiction of more than one centre.

A comparison of the graphic representations of the various models (Fig.1) shows that the differences between K3 and K4 are slight, as the spatial relationships between the settlements do not differ much from one system type to the other. The differences between these two models and K7, however, are considerable as here the settlements do not lie on the boundary lines between two or three centres - the catchment areas of the individual centres are separated by a settlement-free zone. This vacant zone arises as a result of settlements avoiding situations of contention due to the conflicting claims of neighbouring centres. By moving closer to one of these centres such ambiguity is avoided.

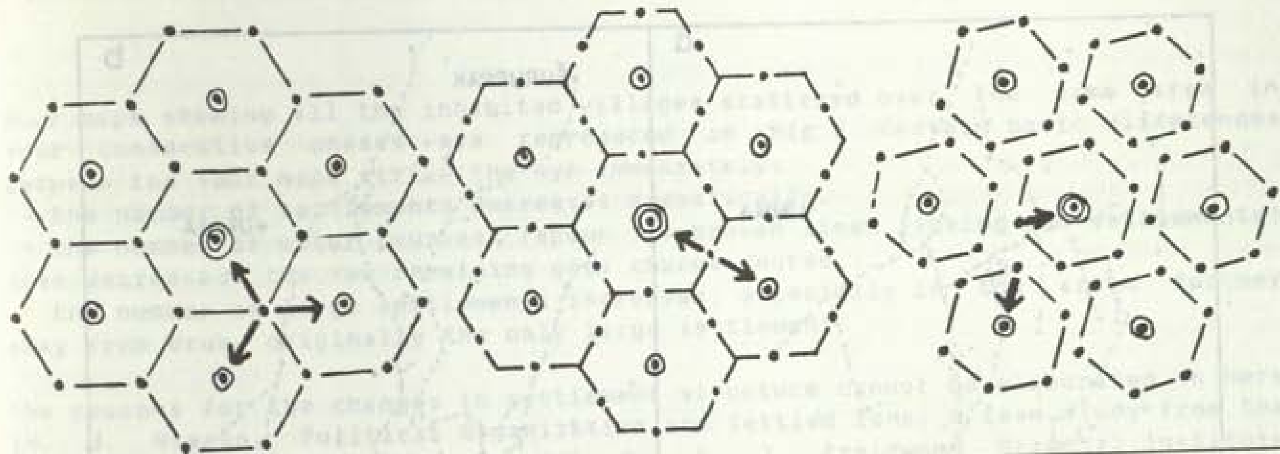

Fig.1

To return to the archaeological context - here the practical possibilities and limitations of the hexagon model become apparent. Although settlement size and distribution is exactly the kind of information that can be obtained from an archaeological surface analysis, we naturally cannot expect ancient settlement networks to form neat hexagons. Thus subtle differences such as those between models K3 and K4 are not to be found in our material. However, this is not the case with the main characteristic of the K7 model - the settlement-free zone - which could more likely be encountered even in an area of uneven settlement distribution.

The possibility already mentioned of arriving at more specific statements on particular settlement systems beyond the mere confirmation of their existence lies, therefore, in the distinction that can be drawn between those systems whose cohesion was economically based and those mainly united through common administrative/political interests.

This can be demonstrated by an example chosen from a geographic region which offers almost ideal conditions for the more or less complete reconstruction of ancient settlement patterns. Extensive tracts of the southern part of Iraq between the Euphrates and Tigris have been uncultivable and therefore uninhabitable for the past 1,500 years. In all this time nothing happened in this area which could have disturbed any older remains. Added to this is the constant wind erosion due to the prevailing high aridity and strong winds which has blown away up to 3m of cultural debris from the ancient settlement mounds in the course of time. Whereas the lightweight remains, such as disintegrated mud bricks, were simply carried away, all the heavier bits were left lying on the surface, particularly ceramic sherds. As a result, most of these mounds are covered so densely by ceramic sherds that it is impossible not to step on them. In fact, there is so much material of this nature everywhere that the former settlements can generally be dated without any difficulty.

This situation is especially true of the environs of ancient Uruk in southern Mesopotamia, investigated by R. M. Adams and myself in 1967 (Adams, R. M. and H. J. Nissen.The Uruk Countryside, Chicago 1972). Apart from collecting a wealth of material from almost every period between the end of the 5th millennium BC and the Islamic conquest which provided satisfactory answers to many puzzling questions, it is particularly the data we obtained on the relatively short time-span from ca. 3,200 - ca. 2,500 BC which can be used to illustrate the models here described.

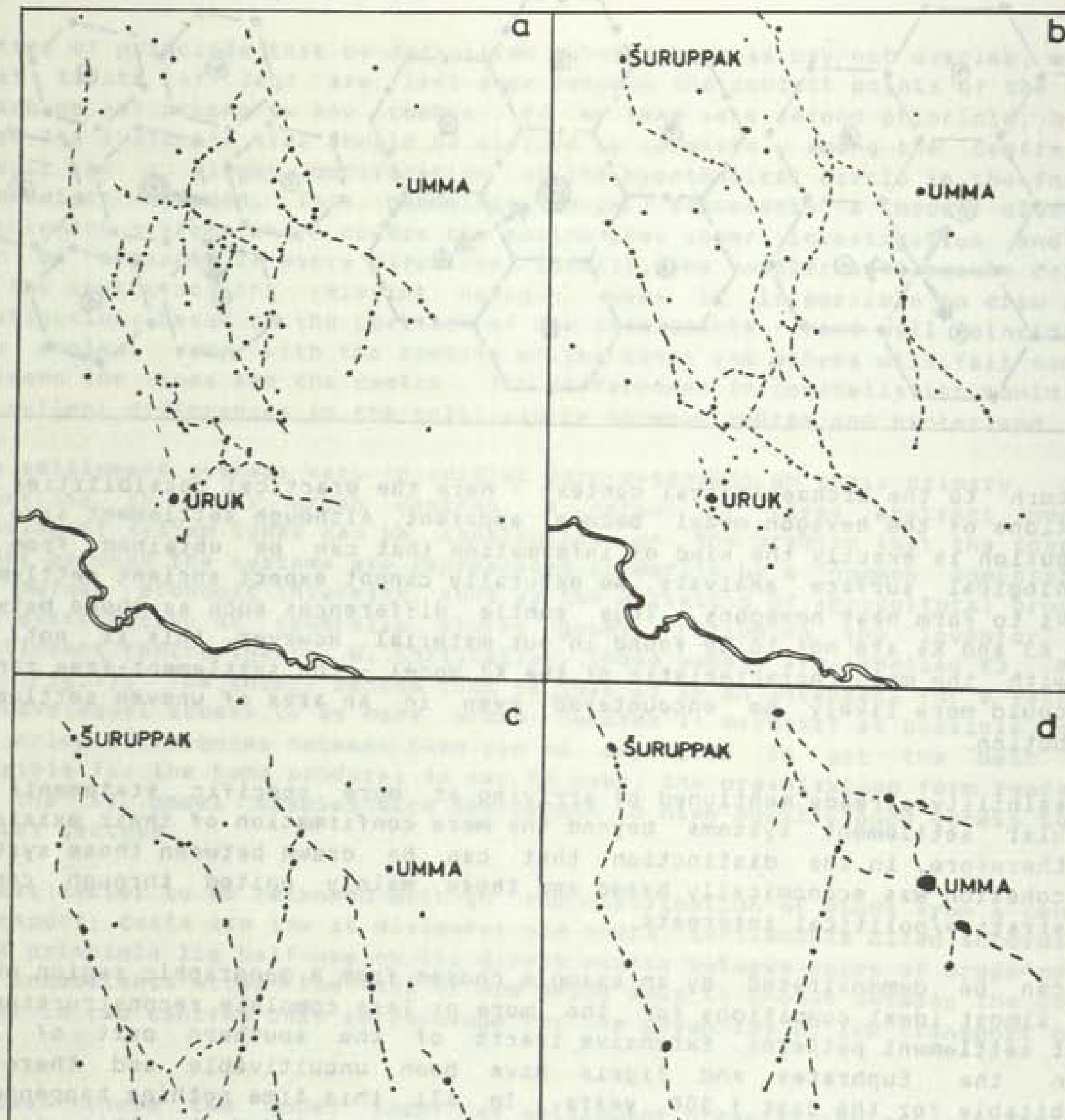
a
UMMA
URUK
b
ŠURUPPAK
UMMA
URUK
c
ŠURUPPAK
UMMA
URUK
LARSA
20 km
d
ŠURUPPAK
UMMA
URUK
LARSA
e
-- Zahl der Siedlungen
— Gesamtbesiedlungsfläche (in qkm)
150
100
50
10
Obed
Früh Uruk
Spät Uruk
Ğ.N.
FD I
FD III
Akkad
Ur III
aB

Fig.2

Four maps showing all the inhabited villages scattered over the same area in four consecutive phases are reproduced in Fig.2. Certain basic differences between the four maps strike the eye immediately:

- the number of settlements decreases dramatically,
- the number of water courses (shown as broken lines linking the settlements) also decreases, the few remaining ones change course,
- the number of large settlements increases, especially in the areas further away from Uruk, originally the only large settlement.

The reasons for the changes in settlement structure cannot be elaborated on here (H. J. Nissen, Political Organization and Settled Zone: a case study from the Ancient Near East; in: Festschrift for R. J. Braidwood, Oriental Institute Communications (Chicago) 1983); instead, the type of change involved will command our attention. The general trend towards a decrease in the number of settlements combined with an increase in settlement size did not occur consistently over the entire area under investigation. The evidence shows rather that this process took place at a faster rate outside an empty, find-free concentric zone around the ancient town of Uruk. Inside this zone the number of settlements decreases, but those remaining do not increase in size. In later phases, the enlargement of the settlements outside the zone takes on a new dimension, in that they shift gradually away from this area and attain a size which puts them on a par with the old urban centre, Uruk, for the first time.

Assuming that the enlargement of settlements was complemented by a parallel increase in power and also that the settlement-free zone here bears the same implications as in the K7 model just discussed, the following possible interpretation is worthy of consideration. While the old urban centre, Uruk, manages to prevent the growth of rival power in its inner catchment area, it fails to do so in its more distant hinterland where it is not so tightly in control. Therefore the boundary between an inner and an outer catchment area controlled by a given power would have been represented by a settlement-free zone which arose as a result of the unwillingness of the settlements in the undefined border area to put with the uncertainty of being or not being subject to direct intervention by the urban centre. It was only where it was clear to which catchment area they belonged, the inner or the outer, that settlements were established in this no man's land. In my opinion, the existence of this settlement-free zone is clear proof of the largely political nature of the relationship between Uruk and its hinterland. This is confirmed by the fact - among others - that the emergence of new urban centres in no way inferior in size to Uruk eventually leads to political conflicts on an enormous scale, as the historical accounts which start about this period testify.

By virtue of the survey results which allow us to observe this gradual growth of rivalling powers we can, for the first time, suggest reasons why all the towns in the period shown in the fourth map appear to be in a state of feud: the trespasses on each other's spheres of interest which blew up into never-ending, insoluble conflicts over boundary areas and canals.

Briefly, a second example may be added as it shows another dimension. The ancient city of Uruk mentioned as the centre of the area discussed before, itself has been a target of a surface reconnaissance. Again because of the masses of pot-sherds on all parts of the surface and because of its datability it was possible to determine at what time a particular area had been inhabited. As here the object was an urban area it was possible to see which parts of the

city were inhabited during which periods.

For comparison we may take the evidence for the phases contemporary with maps 1 - 3 of Fig.2. Admittedly, the survey of the city has been very impressionistic rather than systematic; yet, the trend shown nevertheless may endure more sophisticated approaches (Fig.3). This trend shows a steady growth from a rather small town to a city of almost 6 square km, within the course of 300 years at most.

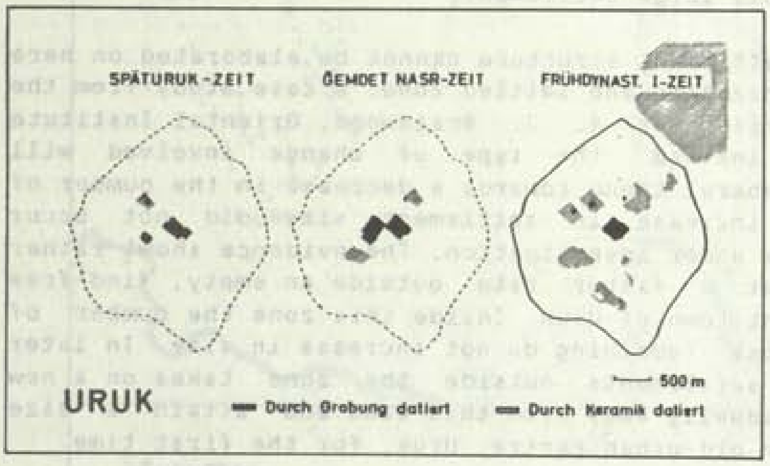

Fig.3

The link with the former discussion is obvious. Whereas in the more distant hinterland the local population concentrated in fewer settlements thus causing the number of settlements to decline with the remaining settlements becoming larger, the development in the immediate vicinity of Uruk was different. Here too the number of settlements declined but none of the remaining settlements grew larger. Instead of this, as we can see now, the central settlement of Uruk drew in the population of the abandoned villages.

Many other examples could be given of problem cases where the results of surface analyses furnished important or even decisive new data. However, it is merely intended here to point out that just as new data can be obtained by analysing entire tracts of land, so too can the intensive analysis of the surface of ancient settlement areas be most productive and informative.

It can be easily imagined that when applied to the Harappan cultural area, similar investigation methods could also lead to results which would provide an insight into the inner cohesion of this still so impenetrable culture.

Übersetzt aus dem Deutschen von Dr.M.Mulloy
Zusammenfassung von C.Müller-Waldeck

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RWTH AACHEN

OUTLINE OF A STRATEGY FOR THE ARCHAEOLOGICAL ANALYSIS AND INTERPRETATION OF A 3RD MILLENNIUM BC POTTERY PRODUCTION CENTRE IN THE INDO-IRANIAN REGION

STRATEGIE DER ARCHÄOLOGISCHEN ERFORSCHUNG UND AUSWERTUNG EINES TÖPFEREIZENTRUMS DES 3.JAHRTAUSENDS VOR CHRISTUS IM INDO-IRANISCHEN RAUM

ZUSAMMENFASSUNG

Um eine brauchbare Strategie für die archäologische Erforschung und Deutung von großen Töpfereiproduktionszentren zu entwickeln, erscheint es sinnvoll, wie folgt vorzugehen:
Die Rekonstruktion dreier grundlegender Aspekte eines jeden Produktionsverlaufs, nämlich
a) des Produktionszyklus (physischer Ablauf der Arbeit)
b) der gesellschaftlichen Organisation der Arbeit
c) der Erstellung eines Musters für die Formen des Kommunikationsflusses
bildet den Rahmen, innerhalb dessen die Erforschung der Töpfereiproduktion durch eine Neubewertung der von der Archäologie gelieferten Indikatoren sowie durch die experimentelle Verifizierung ihrer zunächst hypothetischen Funktionen und Beziehungen zueinander innerhalb der o.g. Punkte stattfindet.
Diese Arbeitshypothesen werden anhand von Beispielen aus den Grabungsorten Shar-i Sokhta, Tepe Rud-i Biyaban 2, Tepe Dash (Sistan, Iran) und Mohenjo-Daro (Pakistan) erläutert.

This paper attempts to outline a series of methodological hypotheses established as a starting-point for the definition of a strategy of research on intensive pottery production areas in protohistorical sites of the Indo-Iranian region. The body of data to which we shall refer encompasses the information acquired between 1969 and 1978 by the Italian Archaeological Expedition in three different sites in Sistan:

1. Shahr-i Sokhta, the largest protohistorical site of Sistan during the 3rd millennium BC, excavated over ten seasons between 1967 and 1978 (Tosi 1968, 1969, 1980; Salvatori 1978);
2. Tepe Rud-i Biyaban 2, a pottery production centre relative to Period III of the Shahr-i Sokhta sequence (ca. 2450 - 2300 BC) that was excavated in the 1970 season (Tosi 1970);
3. Tepe Dash, a large factory site for pottery manufacture, located 2.5km SSW of Shahr-i Sokhta, on which only a surface survey was carried out in 1978 (Tosi 1981).

In order to develop a new systematic approach to the study of pottery production, observations should lead to the reconstruction of three basic aspects of any manufacturing activity:

1. the production cycle (the physical organisation of work),
2. the social organisation of labour,
3. the patterning of the information flow.

Accordingly, our aim is to provide a critical reappraisal of pottery production, as an aspect of craft specialisation, in the light of a more general reconsideration of its indicators available across the archaeological record. We should stress that every production cycle is reflected in the archaeological mirror according to particular dynamics that are a function of its internal structure: the correspondence between segments of the production cycle and segments of available archaeological information is never a simple and direct one. In the case under examination, we are dealing with macroscopic assemblages of indicators relative to certain stages of the cycle (like kiln remains and wasters in pottery firing), while other stages, like forming and drying, are obviously less clearly documented.

THE PRODUCTION CYCLE

The production cycle may be conceived as a continuum of different events to be resolved, with the aim of a structural definition, in a set of hierarchically ordered analytical units (Tab.1). This hierarchical model calls for a series of comments:

a) The production cycle viewed, where appropriate, as an integral unit of the whole production process of a given society, represents ideally the universe to be investigated.

b) Within the pottery production cycle we can isolate three processes:

- extraction and preparation of raw materials,
- forming and finishing,
- firing.

Apart from the employment of different apparatuses, these processes are characterised in our case by a relative degree of differential allocation, corresponding to the different physico-chemical transformations executed. Extraction of raw materials was generally not effected on the site itself, and evidence for it is hardly expected in the archaeological record.

c) The operations, the central units of the model, are abstract unities that, within the framework proposed by Tosi for his study of work allocation, correspond to the "functions of craft", defined as "... minimal units of observation... to be established for each particular craft according to the manufacturing process and the techniques adopted in that given cultural context" (1981: 6). Thus they become the basic and most suitable unities through which to observe the behaviour of the production flow in terms of spatial variability, social organisation of work and patterns of information processing.

d) Within the procedural model here suggested, the degree of relative evidence of transformational activities in the archaeological record decreases according to the hierarchy of the units: therefore we shall have a maximum degree of evidence at the level of the production cycle, versus a minimum one at the level of the micro-movements.

The reconstruction of a production cycle takes two distinct routes:

1. The archaeological record is to be analysed with the aim of redefining the finds in terms of archaeological craft indicators (hereafter ACI) (Tosi 1981: 8), thus establishing a series of hypothetical relationships between types of activities and types of archaeological evidence. It is possible to distinguish two basic types of ACI, corresponding to two analytical stages: artefactual indicators - archaeological finds ordered by Tosi in 6 classes (facilities, tools for manufacture, residues, semi-finished products, stored and unworn products, materials for recycling) - and internal indicators which include a wide range of evidence drawn from internal and archaeometric analyses of artefactual indicators (e.g. internal elements and characteristics of the kilns, wear traces on tools, work traces on the residues etc.). Work traces on the finished product belong to this group, but they are different in that they do not yield information on the allocation of the performed activities.

Archaeometric analysis can extend the range of internal indicators to infinity. Given the continuous interference between these two types of ACI, the proposed distinction is more a formal than a substantial one.
2. The set of the detected indicators is inserted in a dynamic flow of experimental simulation of the production cycle, in which each indicator works as a constraint or a compulsory course. The fundamental role of experimental simulation, in this perspective, is then to function strictly as a homeostatically conceived device that, in a feedback flow of hypothesis-simulation-new hypothesis, works ultimately as a test to verify the hypothesized relationships between the work unities of the different levels and the ACI. The whole system is progressively improved until it attains a state that can be deemed sufficiently fluid.

One of the most important results of this second stage is the association of ACI to specific "craft functions". It should be stressed that not all the operations/craft functions are immediately identifiable in the record. Given this, and the fact that all operations, by definition, are necessarily conjoined within the work sequence, these functions can be identified by the detected indicators of the successive functions; these ACI can be considered and defined as "cumulative indicators".

THE SOCIAL ORGANISATION OF LABOUR

Organisation of labour could be defined as the system which emerges from two spheres of interrelationships:
a) between segments of the producers' group and segments of the physical flow of the production;
b) between sphere a) and different segments of the social structure.

As this analysis is restricted to the production centre, a strategy is needed to investigate the relationships covered by sphere a). Archaeologically, these relationships are expressed in the relative allocation of the craft functions, i.e. in the spatial variability of the relative ACI, within the spatial articulation of the site. By subdividing the site into a coherent set of spatial units (either cultural containers such as houses, rooms, courtyards, open spaces etc., or simple grid units) and ordering them in terms of presence/absence/relative frequency of ACI of craft functions, it becomes possible to recognise in the archaeological record the fossilised imprint of the functional aggregation of one or more spatial units.

This line of approach is actually applied on the surface of the so-called Moneer South area of Mohenjo-Daro, an area with evidence of intensive manufacturing activities, by the German Research Project with Italian cooperation. Here the scattering of ACI within the grid units is recorded as a function of the spatial variability of the transformation activities performed. In this case the distribution of the indicators along the slopes is further affected by the intervention of post-depositional factors (mainly wind and water erosion) whose behaviour dynamics have to be reconstructed and defined in order to relocate the assemblages in their primary situations.

Structural analysis of architectural installations permits the establishment of presence/absence of relations of selective or privileged access between the units previously characterised by function. In the open spaces, the existence of similar relationships could be investigated by developing a proper methodology for the archaeological identification of the ancient paths (for an ethno-archaeological example of observations on paths cf. Deboer and Lathrap 1979). This phase of spatial analysis could function as a test to verify the functional relationships previously isolated. The final result, therefore, is the isolation, within the site, of one or more acivity areas expressed as

clusters of ACI, of their specific roles within the manufacturing cycle, as well as of their relationships of spatial reciprocity.

THE PATTERNING OF THE INFORMATION FLOW

Positing the argument in (somewhat old-fashioned) metaphorical terms, it can be seen that once the composition and the circulation of the blood (the physical flow of production) and the nature of the organism in which it moves (the social organisation of labour) have been defined, it should now be necessary to investigate the structure of the nervous system (the patterning of the information flow). We shall therefore look in the archaeological record for all the indicators that can be deemed as "... material expressions of the institutionalized processes of social control..." (Tosi 1981: 33) over this specific sector of the economic system. The following three observations offer a serviceable line of approach:

a) All the material culture may be conceived as an integral part of a set of communication processes.

b) The study of ceramic assemblages in the Indo-Iranian region in the 3rd millennium BC reveals the existence of forms of communication related to pottery production and use. The difficulty of defining these phenomena analytically renders them rather elusive to direct interpretation. These include, among others, the collection of graphic marks on the vessels from the graveyard of Shahdad (Hakemi 1972, passim), the corpus of signs from Tepe Yahya (Potts 1981), the codices of signs from Shahr-i Sokhta (Tosi 1980a: Fig. 9) and Damb-Sadaat (Fairservis 1971: Fig. 35), the presence of sealings on pots, apparently rare but known from sites such as Shahdad (Hakemi 1972: Pls. XXII B, XXIII B, XXIV B, C), Shahr-i Sokhta (Lamberg-Karlovsky and Tosi 1973: Fig. 48) and Mohenjo-Daro (Marshall 1931: Pl. CXV, 558-560). Recently, the corpus of drawings registering the pottery of Shahr-i Sokhta II-III has been structured according to the assumption that it could be an expression of a set of functions of communication (Pracchia 1981).

c) All this archaeological evidence represents the available record of forms of communication and bits of specific information of which we recognise the media, while function and/or meaning have rarely been systematically investigated.

In the evaluation of finds qualified to be archaeological indicators of information processing (hereafter AIPI), we postulate that these devices comprise a wide and heterogeneous group of "tools for doing" as opposed to "tools for making" (Mitcham 1978: 234). Within a production cycle, they may be considered as the material embodiment of different forms of specialised information, with the function of regulating and controlling the different stages of the production flow. We no longer take into account the possibility that such devices were expressions of communicational forms extraneous to the functional logic of the production cycle. Tab.2 shows an attempt to integrate the administrative devices considered by Tosi in his test on Shahr-i Sokhta with the indicators of information processing available, or, in some cases, generally expected from the picture we have of protohistoric Sistan.

The two basic groups of AIPI are divided according to their presumed functions within the production flow. These functions, generating four clases of indicators, have been defined as follows:

1. Determination of physical dimensions

If weights are not infrequent in the 3rd millennium BC assemblages of the region, devices for standard linear measurement seem to be much rarer. Furthermore, their presence in the archaeological record of a pottery production centre is rather improbable: even today potters employ such improvised standards as sticks to take measurements. Very often the dimensions of the product are drawn from pre-existing artefacts; this offers an interesting example of objective communication. Conical objects that could have been true pyrometric

cones have been found on the surface of Tepe Raikes, a mound close to Shahr-i Sokhta (Fig.1, A).

2. Record-keeping of numerical entities of fractions of the flow
With the term "counters" we refer to the small geometrical objects integrated by Tosi in the group of finds indicating administrative activity (1981: Tab.3). "Tally discs" are tablet-shaped clay objects with a sign on one face and tallying nicks on the other; they are administrative devices known to date only from Shahr-i Sokhta and Mundigak (Tosi 1981: Fig.12). If we consider tally discs as semi-permanent recording devices of quantitative dimensions of fractions of the flow at rest or in motion, we can consider the counters primarily as non-permanent devices with the same function, or as counting elements used to make a permanent record of the information.

3. Control of the integrity of pre-stated fractions of the flow
The function of clay sealings in the administrative system has been widely discussed by Ferioli and Fiandra (1979) and Tosi (1981). It is possible to distinguish between functions of control executed on fractions in a state of rest (sealings with reverse imprint of pegs) and in a state of movement, i.e. on materials ready to be transferred (reverse imprint of packages and movable containers).

The fourth class of AIPI includes a wide range of indicators that could be called "graphic":
the same seals are the objective crystallisation of a graphic denotation to be reproduced indefinitely. Seals, sealings on pottery, potter's marks and other pieces of evidence are grouped under the common functional denomination of "relational determinants". With this difficult term we want to stress their common characteristic of expressing, in the widest sense, relationships between at least 6 variables: individual/producing group/society on the one hand, and unit of production/fraction of production/complex production on the other. It is clear that this class is not homotaxial with the others.

The level of information available to date calls for a series of tests to define the specific functional meaning of such indicators inside every particular cycle. The aim is to extract the graphic indicators from the fourth class and to insert them in the first three, or create new ones. For example, the discovery at Shahdad of a Proto-Elamite inscription incised on the rim of a jar referring to the nature and dimension of the contents (" 60 Maß süßes Regen (Wasser) ") (Hinz 1971: 23) documents the use of writing on pottery for the "determination of physical dimensions", but, at the same time, would also document a new class: "determination of the type of commodity contained". Also on record, still at Shahdad, is the use of numeral marks, on a set of pots, to indicate a scale of relative capacity (Salvatori 1978a: 5).

These two examples are useful illustrations of a fundamental characteristic of the relational determinants: their high degree of dependence on archaeological contexts of extremely variable dimensions. In the example first mentioned, the text is meaningless unless it can be seen in relation to the pot and its capacity: the single pot is the primary context of analysis. In the second case, every single pot is the context of its mark, but the system becomes meaningful only in the larger context formed by the existing relationships between scale of capacity and series of marks. In a third hypothetical case, a series of pottery marks referring to the individual producer would require as the primary context of analysis the whole contemporaneous production of a given site. We suggest that the clusters of ACI/activity areas previously isolated are necessarily the primary context, in a production site, for the understanding of the functions of this class of AIPI.

The complexity of the phenomena to be investigated is well illustrated by the pottery sequence of Shahr-i Sokhta and by the assemblage of Tepe Rud-i Biyaban 2.

At Shahr-i Sokhta, the so-called potter's marks appear sporadically in Period I, in the form of simple painted tracts or splashes of colour that could be interpreted as colour proofs (Fig.2, top left). In Period II, a true code of painted signs was in use, found in the majority of cases on the bottom of the pear-shaped beakers - a type intensively produced (Vidale 1981) - and only sporadically on other pottery types. In spite of our previous assumption, in Period II at least one type of mark, known also from Mohenjo-Daro (Figs.3, 4), appears as a variant of an anthropomorphic characterisation of a pot.

In Period III painted marks disappear, to be replaced by a complex of incised signs (Fig.5) spreading, this time, to several pottery types and, in the Rud-i Biyaban material, to some classes of tools for manufacture. This innovation implies that, in Period III, the pots were marked immediately after throwing. Nevertheless, painted tracts were sometimes superimposed over incised signs, thereby documenting a two-stage form of information processing within the cycle (Fig.1, B).

The kidney-shaped smoothers of Tepe Rud-i Biyaban 2 (Fig.1, C; Fig.6) were made by reutilising the rims of broken bowls. Signs often appear on this class of tools which have been incised into the pottery with a pointed implement. Some signs included in the list of those found on the vessels are also present (cf. Fig.6 and Fig.5, middle right; also Tosi 1980: Fig.9). Other signs, more complex, are true iconic representations (Fig.1, C) probably belonging to different communication processes.

The truncated cone-shaped moulds (formerly also known as "jar-stands") are a distinctive artefact type in the assemblages dating to the late 3rd millennium BC in an area extending from Turkmenia and Bactria to Sistan and the Indus Valley (cf. Hlopina 1974). The clay was pressed inside a reverted mould placed on the wheel to form the lower part of the pot, and on top of this part the rest was thrown. The specimens from Tepe Rud-i Biyaban 2 often show on the exernal face a wide range of signs incised after throwing (Fig.1, D; Fig.7). On one of the best preserved specimens (Fig.7; Tosi 1980a: Fig.8), these signs are organised in a form of writing which can be considered to be related to Proto-Elamite (Meriggi 1977). On the internal face two completely different signs are incised (Fig.8): the clay pressed inside the mould retained the positive impression of the signs. In this case, we are dealing with a true "pot-seal" directly connected with manufacture, tool and product. The same tool performs simulataneously two different roles of information processing.

This incursion into the Sistan evidence was intended to give some exemplification of the interpretation problems inherent to the analysis of the AIPI which qualify as relational determinants.

A phenomenon like that of the potter's marks has often been considered in a historical perspective, as a possible formative stage of writing. The most convincing attempt to prove this case is probably the recent contribution by Durrani (1980) regarding the signs from the Rahman-Deri pottery. It should be stressed that the analysis of the AIPI at the synchronic level, conceived as material remains of forms of information processing linked to the relationships of production, is an integral part of every strategy of research aimed at reconstructing an extinct production system.

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I am deeply indebted to Thelma Lowe for her information on the meaning of the truncated cone-shaped moulds.
Many thanks to Susan Adler for revising the English version.

Zusammenfassung von C.Müller-Waldeck

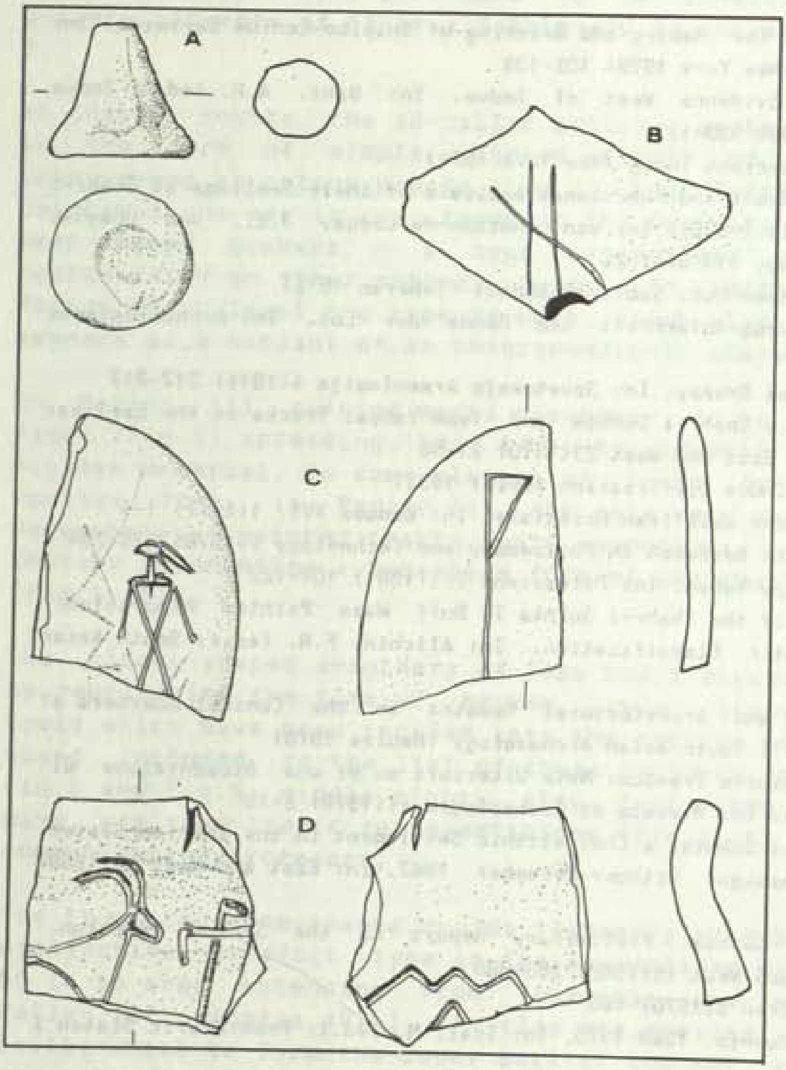

Fig.1
A: Tepe Raikes, surface. Possible pyrometric cone.
B: Tepe Rud-i Biyaban 2. Sherd with incised sign and superimposed colour splash.
C: Tepe Rud-i Biyaban 2. Fragmentary kidney-shaped pottery smoother with incised signs.
D: Tepe Rud-i Biyaban 2. Fragment of rim of truncated cone-shaped mould with signs incised on both internal and external surfaces.

Fig.2
Sahr-i Sokhta, Periods I (top left) and II. Painted signs on the bottom of pear-shaped beakers.

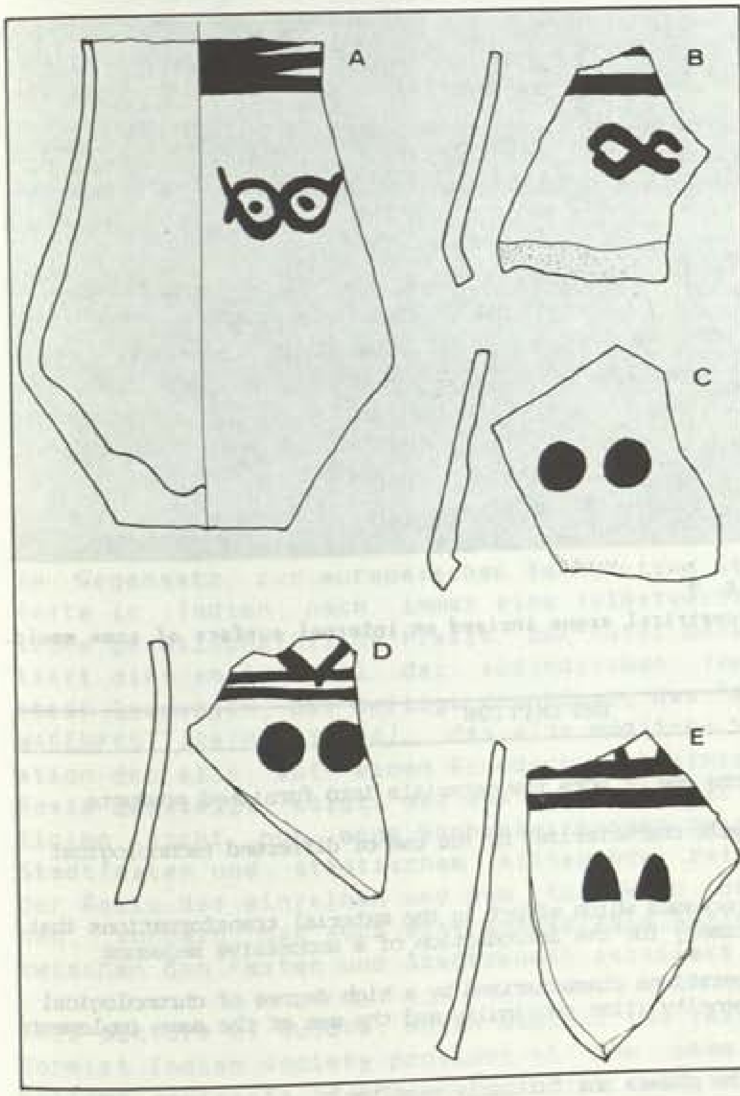

Fig.3
Shahr-i Sokhta, Period II. Fragments of pear-shaped beakers bearing eye-type signs. C and D were made by pressing finger tips coated with paint onto pot; cf. Fig.4.

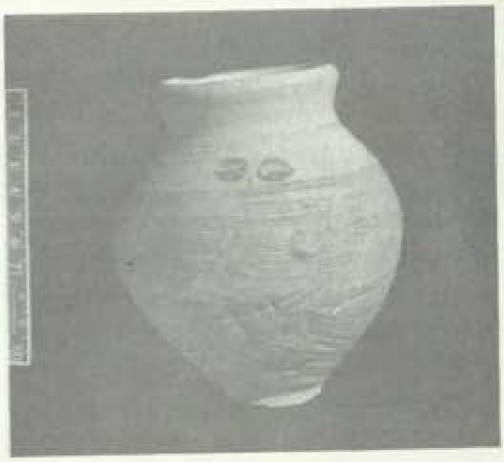

Fig.4
Mohenjo-Daro. Eye-type sign on small painted jar. By courtesy of British Museum.

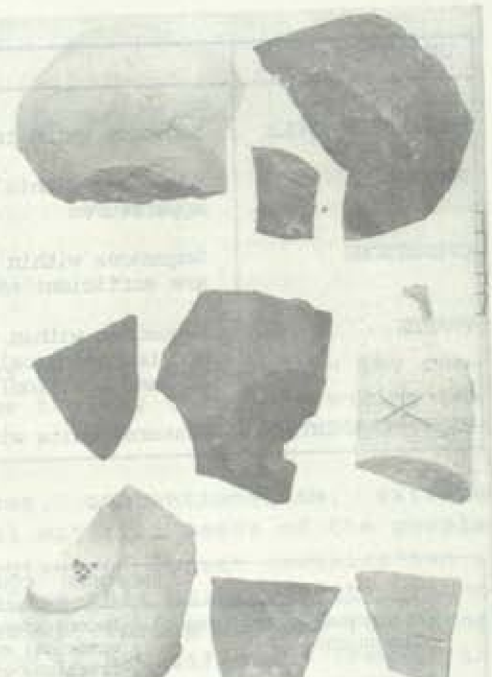

Fig.5
Tepe Rud-i Biyaban 2. Sherds with incised signs.

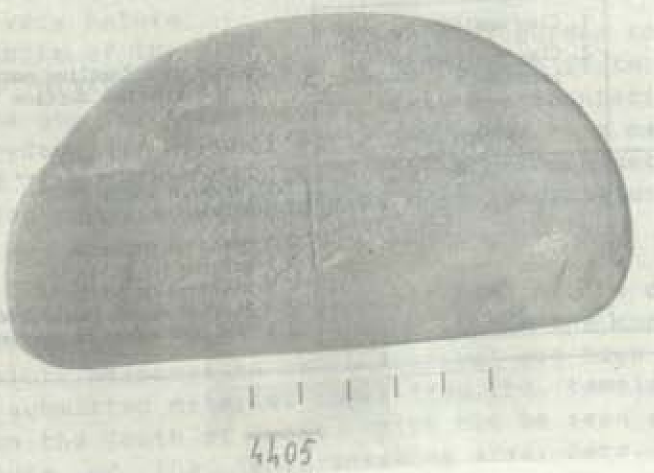

Fig.6
Tepe Rud-i Biyaban 2. Kidney-shaped pottery smoother with incised signs.

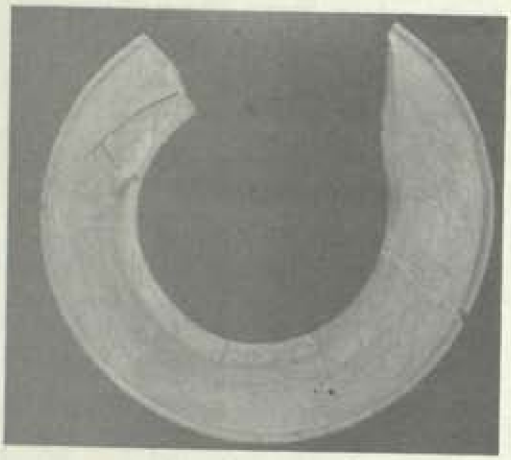

Fig. 7
Tepe Rud-i Biyaban 2. Fragmentary truncated cone-shaped mould with possible inscriptions of Proto-Elamite type on external surface.

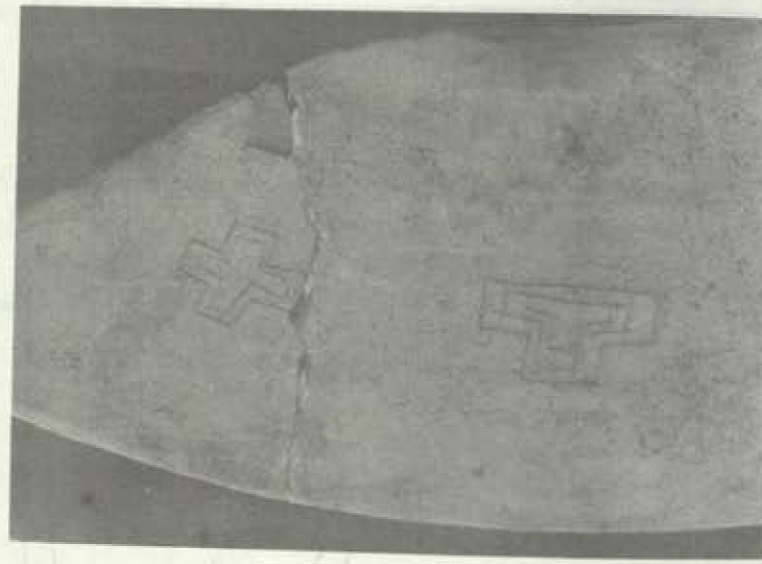

Fig. 8
Geometrical signs incised on internal surface of same mould.

UNITIES	DEFINITION
PRODUCTION CYCLE	Sequence which transforms one or more raw materials into furnished products
PROCESSES	Sequences within the cycle characterized by the use of differend technological apparatures
OPERATIONS	Sequences within the processes which effect in the material transformations that are sufficient and necessary for the introduction of a successive sequence
PHASES	Sequences within the operations characterized by a high degree of chronological and technological homogeneity (time continuity and the use of the same implement or hand position)
MICRO-MOVEMENTS	Gestural units within the phases not furtherly resolvable

Tab.1

	PROPOSED FUNCTIONS			RELATIONAL DETERMINANTS
	Determination of physical dimensions	Record-keeping of numerical entities of fractions of the flow	Control on the integrity of pre-stated fractions of the flow	
ARTEFACTUAL INDICATORS	1. Weights 2. Tools for linear measurement 3. Tools for temperature measurement	1. Counters 2. Tally disks	1. Clay sealings on pegs 2. Clay sealings on packages	1. Seals 2. Moulds with "sealing marks" on the internal surface
INTERNAL INDICATORS				1.1 Marks on tools 1.2 Writing on tools 2.1 Marks on products 2.2 Writing on products 2.3 Sealings on products 2.4 Painted drawings on products 2.5 "Relief" marks on products

Tab.2

JAN PIEPER
LEHRSTUHL FÜR STADTBEREICHSPLANUNG UND WERKLEHRE
RWTH AACHEN

FESTIVALS AS A MATTER OF COURSE IN THE PUBLIC LIFE OF TRADITIONAL INDIA

DIE SELBSTVERSTÄNDLICHKEIT VON STADTFESTEN IM ÖFFENTLICHEN LEBEN DES TRADITIONELLEN INDIEN

JUST AS NAMELY, O BAHUNA, A BLUE, RED OR WHITE LOTUS FLOWER - SPRUNG UP FROM THE SWAMP, GROWN UP IN BRACKISH WATER - RISES ABOVE THE SURFACE OF THE WATER AND STANDS THERE UNTOUCHED BY WETNESS, JUST SO, O BAHUNA, DOES THE ACCOMPLISHED TARRY WITH ABSOLUTE PEACE OF MIND.

(Anguttara - Nikaya,X,81)

ZUSAMMENFASSUNG

Im Gegensatz zur europäischen Kultur sind Stadtfeste in Indien noch immer eine selbstverständliche gesellschaftliche Praxis. Der Autor dokumentiert dies am Beispiel der südindischen Tempelstadt Srirangam; das dortige Hauptfest, das "GROßE WAGENFEST" (RATHA YATRA), das eine mögliche Variation der alle auf einem Grundschema basierenden Feste darstellt, zeigt, daß auf der Basis der Religion nicht nur enge Wechselwirkungen zwischen Stadtfesten und städtischem Alltag bzw. zwischen der Rolle des einzelnen und dem Kollektiv bestehen, sondern daß auch eine ausgeprägte Beziehung zwischen den Festen und Stadträumen existiert.

This picture of Buddha, which depicts the religious genius' position in the conformist Indian society provides at the same time the key to understanding the extreme contrasts of the whole Indian culture.

While the caste system, untouchability, food taboos, conventionalism, extreme fears of pollution and most of all the proverbial material needs of the people constitute the sufficiently wellknown daily routine of Indian civilization a hardly imaginable richness of festive life rises above this daily variety round - as if it were the lotus of this misanthropic swamp, sprung up from it, being firmly rooted in it and only able to survive from it but different from it in its very nature.

In spite of the enormous historical burden this society had to take on from its long history and which still burdens it to the utmost, this society has kept a naive joy for spectacular self-representation and colourful aestheticizing of everyday life as well as it developed as a matter of course the playful dealing with all phenomena which the senses can get hold of and which our civilization turned colourless through lack of imagination only knows as a memory or nostalgia.

The reason for this development need not be discussed here, the fact however is remarkable enough to give - within the context of this paper - an idea of the possible meanings an urban festival can have under favourable social conditions. The submitted material comes from the temple town of Srirangam (10.52 N; 78.44 E) in the South of India, which can be seen as a typical example of the urban culture of the Tamil-speaking area; here, however, the relation between urban area and festivals are more distinctively marked than elsewhere.

We have to confine ourselves to describing only the festival of the "Great Chariot" (Ratha Yatra) which marks the highlight in the calendar of festive events.
The documentation was planned in such a way as to explain first of all how the whole cultural context has to be constituted if festivals are to be a natural social practice.
Instead of using an example from India we could look back through European history as well: the so-called "Schembartslauf" of Nuremberg, the festivals of the Medici family, the medieval "Trionfi", the maritime urban rituals of the Republic of Venice, all these are urban festivals which might have expressed a similar outlook on life as is documented even today by the "Ratha Yatras" of South India.
But in those cases we would have to reconstruct the social context wholly from written fragments, from hints and marginal notes, which are the poorer as the reasons for these events were still so much an urban matter of course for the chronicler that for him they seemed not worth recording.
In contrast to this if we examine the urban culture in India under aspects of architectural anthropology has the advantage of being able to experience every detail in its context. We have the clear-cut facts in front of us which we could otherwise only guess from history.
And precisely the details and the seemingly minor matters of the documentation, are important, because they show the close correlation between festivals and everyday urban life, the whole course of the processions with the characteristic traits of urban architectural structures,the role of the individual in the community, in short: the close relationship of all details with an absolute unity formed out of dream and reality,thus a unity which also longs again for a 'desire for festivals'.

The Ratha Yatras are the most spectacular events in the calendar of festive events. On the last day but one of the festivals thousands of people pour into town to pull together with the townspeople a huge multi-storeyed temple chariot through the streets of the town; the festivals are named after this event.
The chariot festivals however are not the only big events in the rhythm of urban life.
During the year a town in South India celebrates as a rule eight big festivals each of them having up to 25 pageants, processions, mystery plays or similar street events. The festival's main event usually coincides with the full moon of the month when the festival takes place. In spite of the richness and variations of the events the festivals follow a simple basic plan which is merely modified even for the chariot festivals.
A temple in South India has always two idols. One idol is usually a big sculpture made from stone which is fixed permanently in the cella, the other is a small figurine cast out of five metals. In most cases it is placed in the base of the main figure or in a shrine in the latter's immediate proximity; on holidays, however, it is taken out, decorated and carried through the town.
This is where the Indians' whole richness of imagination displays itself in the variation of a simple theme.
To begin with we can divide the festivals into two groups according to their course of action, in festivals which consist mainly of theatrical performances, mystery plays, magic actions,dances etc. - that is of purely representative character in front of the mass of people an in festivals which are primarily made up of circumambulations, processions and pageants, this means of course a more active participation on the part of the people.

Every festival has its own area. Some are solely confined to the actual temple

district, others to certain streets, and the bigger festivals extend even to the area surrounding the town with circumambulations which can last several days.

A further variation can be found in the different vehicles which transport the idol. Besides the classical travelling coaches of Indian Rajahs, the palanqueens, litters, canopies, a great amount of different carriers are used which are installed on larger-than-life size wooden and gilded or painted pack animals. Such a device is called "Vahanam" and it takes approximately ten to twelve men to carry it.

At the climax of the main festivals the idol is placed on an especially big "Vahanam": on one of the wooden temple chariots (Ratha) - a fairly big town possesses three of them - or in a floating pavilion which is moved around the tank at night by using long punt poles.

Indian urban festivals are always the vehicle of religious meaning. Their origin is derived from the pastoral intention of presenting the idol to the public, to the mass of people it is otherwise barred from in the inner part of the temple. Here we have a certain similarity with the processions of the Catholic world which also developed from the attempt to present the sanctuary to the people. With this, however, the analogy comes to an end.Because the Indian conception of religion differs so greatly from the Christian one we refrain from using the same term for something so different. This is true above all for two categories which can be seen as main reason for urban festivals being such an essential component of the townspeople's life in spite of their religious contents.

Hinduism does not distinguish between sacred and secular spheres. Consequently, the sacrerd sphere is not separated from the real world but constitutes its intrinsic nature. Therefore urban festivals are not a glorification of supernatural forces from another world but an euphoric avowal of urban society. Linked with this is also the fact that urban rituals never express a solemn keynote but are always the expression of common joy of living.

These technical details illustrate how intrinsically the festivals form part of the character of the town.
Special types of buildings are developed as for example Ratha Mandapam, Ghats and chariot sheds to make festivals possible, special festival areas are planned inside and outside of the town and built up accordingly, as the tank in the West and the Singha Perumal Kovil in the East, even the physical structureand construction of the town and with this its functionality conform requirements of the festivals.
Especially the tow passages at the four corners of the square streets show the exceptionally close link between the festivals and the town's architectural structure. They can be found in almost every town in South India and they give a clue how essential these ephemeral aspects which are usually regarded as peripheral subject belong to the overall picture: in fact they are so essential that the courses of the processions are the key for the understanding of architecture and urban space, so essential that central qualities as route configuration, housing development, orientation and value of buildings are subordinated to the technical necessities of the festivals.
And this applies generally to the role of festivals in the life of towns in southern India.

If the documentation of chariot festivals proved one thing it is the fact that we are not dealing with decorative customs of a minor sphere of tradition but with a crucial event of the town's public life.
(The documentation at the end intends to show in detail how the general traits

of festivals in South India vary and are organized. It is arranged in four series which illustrate different aspects of the festivals:
A. Spatial structure of town;
B. Paraphernalia and choreography of the pageants;
C. Technical details of the festivals.)

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Translation and summary by C.Müller-Waldeck

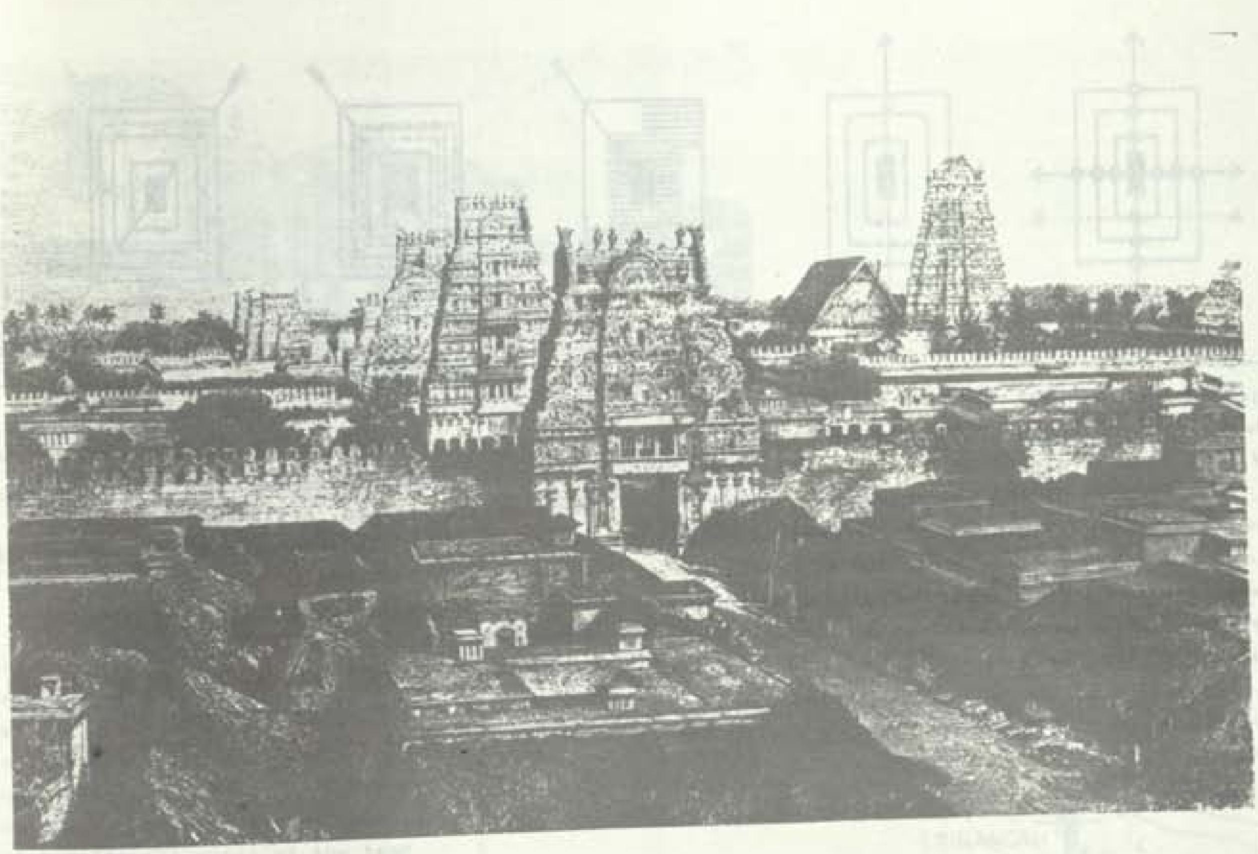

Fig.1
Srirangam on a 19th century etching. View from the South over the row of Gopurams (gate towers) at the North-South-axis.

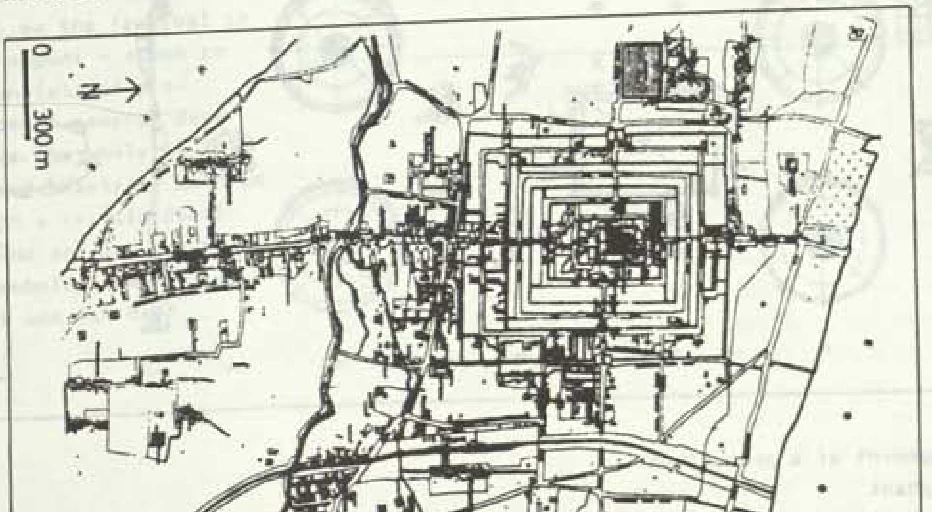

Fig.2
Map of Srirangam. The town consists of seven concentric ring walls, of which the first three from outside surround the residential quarters, the inner four surround Raganatham's temple with its shrine, pillar halls, stores and stables. Approximately 25.000 people live within the walls. The town is divided by an orientated system of coordinate axes; the North-South axis connects the Ghats (bank terraces for ritual ablutions) at both arms of the river which surround the isle of Srirangam, the eastern axis and the northern axis lead to two other districts of ritual importance in town, to the tank for the floating festivals in the West and to the cremation ground and burying place of the lower castes in the East.

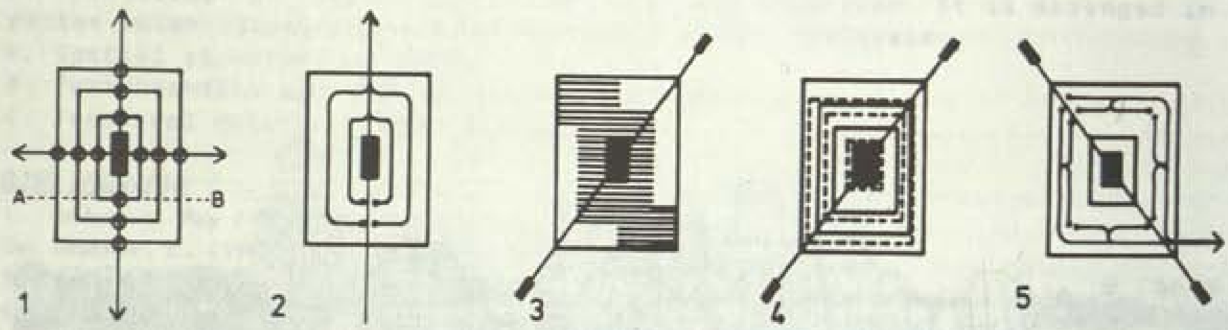

Fig.3

The basic symmetry according to which the plan of Srirangam is organized.

1. The symmetry of the gate towers, ring walls and the hierarchic districts surrounded by them built up on the orientated system of coordinate axes. A,B: Raganatha Swami Mandapam and Singha Perumal Kovil, the most important ritual structures near the town.
2. The system of the Brahmins' funeral ways corresponding to the symmetry of the coordinate axes.
3. The social topography in folding symmetry to the NE-SW-diagonal. The Brahmins' residential quarters are hatched, not shaded are those of the agricultural labourers in the NE as well as those of the craftsmen in the SW.
4. The ringstreets (dotted line) in folding symmetry as well to the NE-SW-diagonal.
5. The Non-Brahmins' funeral routes in folding symmetry to the NW-SE-diagonal. In the SE the lychgate which is used only for this purpose.

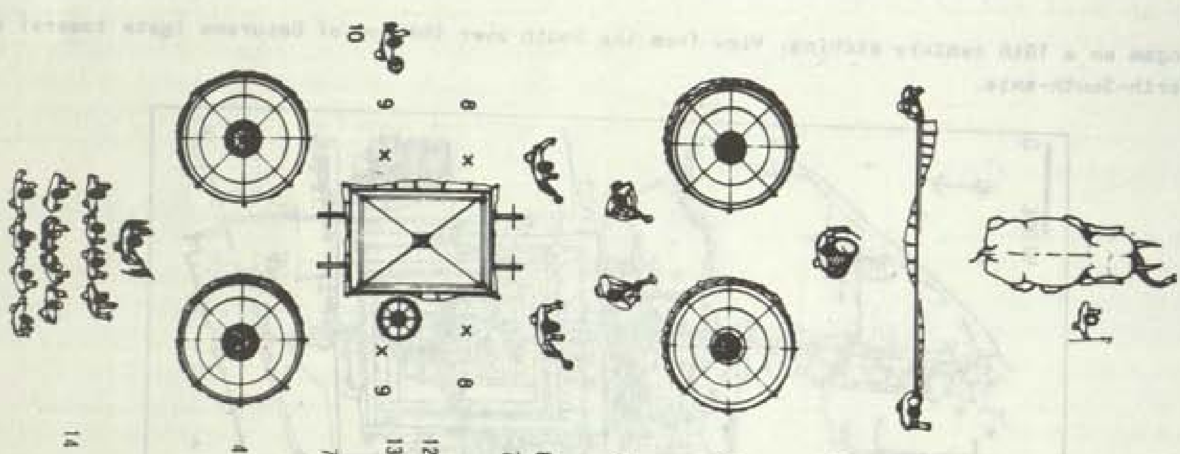

Fig.4

Standard arrangement of a procession

1. Temple elephant
2. Toram (barrier)
3. Drummer
4. Parasols with frills and silver-mounted shafts
5. Wind-players (Nagasvaram, an instrument related to the oboe)
6. Guardians with silver-mounted clubs
7. Pallet (Vahanam), on which the idol is carried
8. Torches in the form of a shell (emblem of Vishnu)
9. Torches in the form of a wheel (emblem of Vishnu)
10. Oil carriers with a bucket of Ghee used as fuel for the torches
12. Canopy
13. Brass parasol, symbol of royalty
14. Brahmins, reciting the Vedas

Fig.5
Kudirai-Vahanam: Instead of a pallet the idol may travel as well on a number of further carriers, as for example on the "Golden Horse" as can be seen above or on other mythical plants and animals.

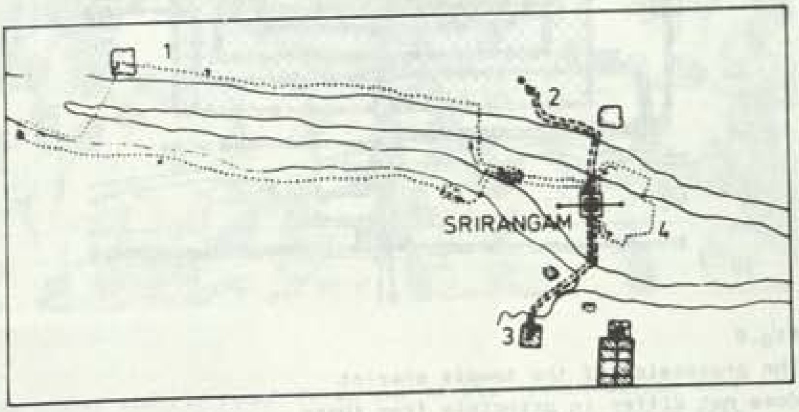

Fig.6
Each day of a festival in Srirangam has its climax in one single or several processions at which - as shown before - not only different emblems are carried around, but at which different parts of the town are circumambulated, too, as well as different destinations are visited every time.
Some festivals, as the festival in the month of Phanguni - shown in the sketch - consists of processions which last several days and also include the whole of the town's hinterland (Ksetra), both as processions with a certain destination on the 2nd and 3rd day and also as circumambulations of the isle on the 1st and 4th day.

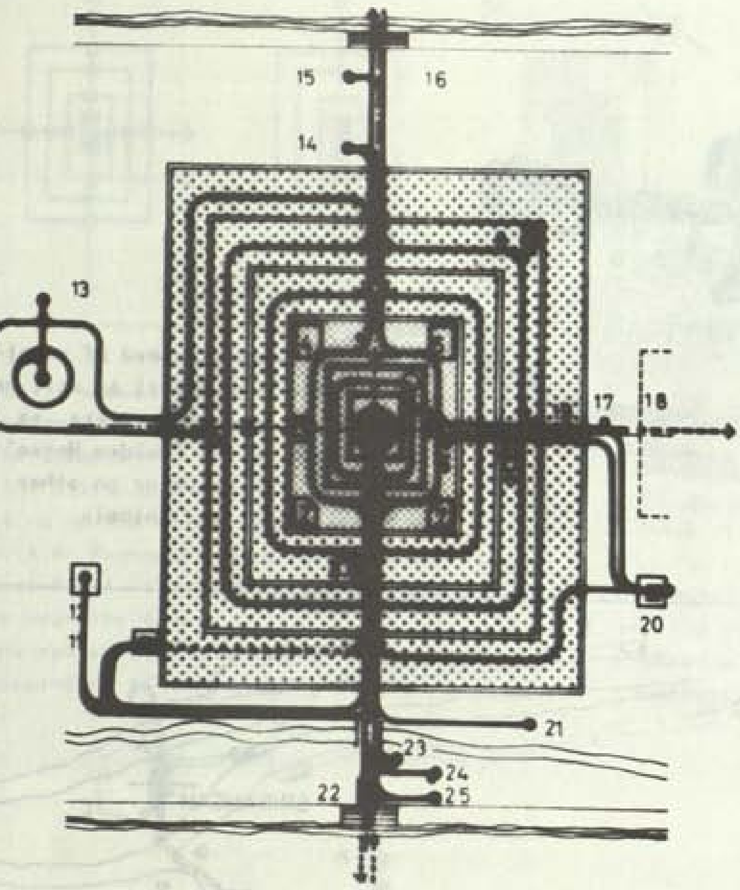

Fig.7
Diagrammatic representation of all ways which are circumambulated every year within the town and within its proximate approaches. On this occasion the symmetries - as sketched in fig.3 - given with the spatial structure of the town are taken and playfully modified both the immediately physically perceptibles - as the alignment of the gate towers and the orientation and quadri-partition connected with it - and the spatial peculiarities not directly visible of the urban architectural structure as for example the social topography the prescribed funeral ways and the gates with ritual taboos imposed on, directions and streets.
So periodically the festivals bring about the real and imaginary connections of urban space, social system, concepts of values and order thus making them physically perceptible.

Fig.8
The procession of the temple chariot does not differ in principle from those of the other festivals; the elephant comes first, then follows the Toram, the musicians, guardians etc. Here, however, the vehicle of the idol is a huge wooden temple and this increase of scale brings forth a stronger participation of the mass of people, a fact which can be seen as one reason that the three most important festivals celebrate their climax with this spectacular procession. The construction of the chariot represents the temple towers' architectural forms and their intrinsic meaning, thus disclosing its function as the idol's mobile dwelling.

Fig.9
The temple chariot is made wholly from timber and its rough forms due to its construction make it seem to be a toy for giants which have got into the company of dwarfs; an impression which fits generally into the playful keynote of the festivals and which furthermore carries off the real events to the edge of wonderland through the use of this archetype from the realm of fables. The chariot is drawn by approx.600 people who hold the heavy towropes cheek by jowl. At this moment the segregation and division in innumerable castes and subcastes whose relations are settled more by taboos than by social conventions, and which works so efficiently in Indian everyday life are suspended for the duration of the festival and urban society celebrates itself as a homogeneous whole.

Fig.11
The chariot of Srirangam weighs approx. 12 to 15 tons. As friction losses are very high with this simple chassis the townpeople's pulling-force does not suffice to get it moving. Therefore long levers are applied behind the wheels which are set in motion by body weight and tow so that a short impulse is given to the chariot as a kind of 'take-off'.
The coordination of the mass of people who move the chariot is not done by orders but by music. For this purpose a drum is fixed under the end of the chariot on which a steady rhythm is beaten as long as the procession moves. In case the chariot threatens to stop the drummer tries to encourage the crowd by faster rolls of the drum. If there is nevertheless a stop he stops beating the drum and the Nagasvaram player (no:5 in fig.4 and fig.10) who sits high on the chariot at the Ratha Yatra blows a rising melody at which the levers are applied. They are moved with the first roll of the drum the chariot gets an impulse and at the same time the crowd starts pulling.

Fig.10
For the duration of midday heat the towropes are put down and people retire into their houses. Aged and ailing people and children who are not able to partake actively in the procession use the opportunity to touch the towropes thus participating symbolically.
The chariots are purposely constructed for the day of the festival they are needed: the wheels are overhauled, fitted with new iron hoops and pushed on the axles, and the multi-storeyed supporting framework for the tower-construction's frills out of prefabricated elements is put on the richly carved and firmly timbered chassis; a process as strenuous as the construction of a half-timber house.

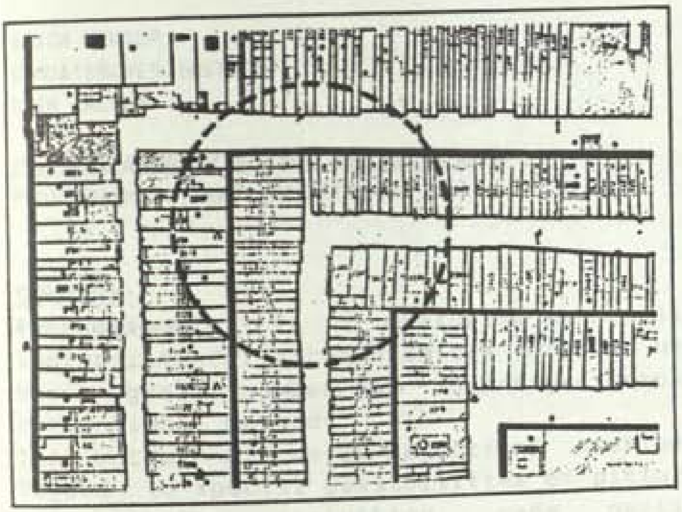

Fig.12
Turning the chariot around the corner presents special technical problems. To pull the chariot up far enough and to leave enough space for the towropes small blind passages run straightway towards the wall at the four corners (comp. detail in fig.12). The chariot having reached the corner the towropes are shifted from the passages to the street and they can pull into the new direction.
The steering of the chariot is made possible by greasy chocks which are held in front of the inner part of the wheels (Fig.13) so that the monster changes its direction inch by inch.

Fig.13

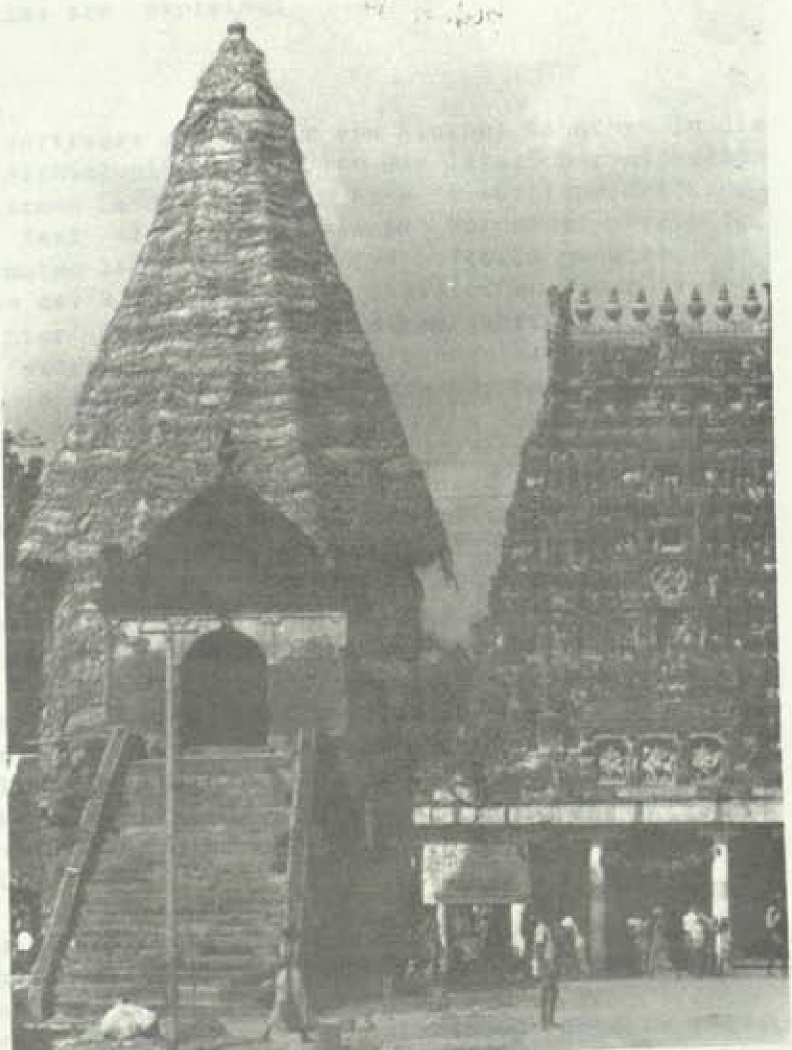

Fig.14
After the end of the festival the chariots are dismantled and 'parked' under shelters plaited from palmleaves, where they stay till the next Ratha Yatra. On the left a Ratha Mandapam can be seen, a pavilion which serves for the ritual 'loading' and boarding of the chariot at the beginning and at the end of the festival.

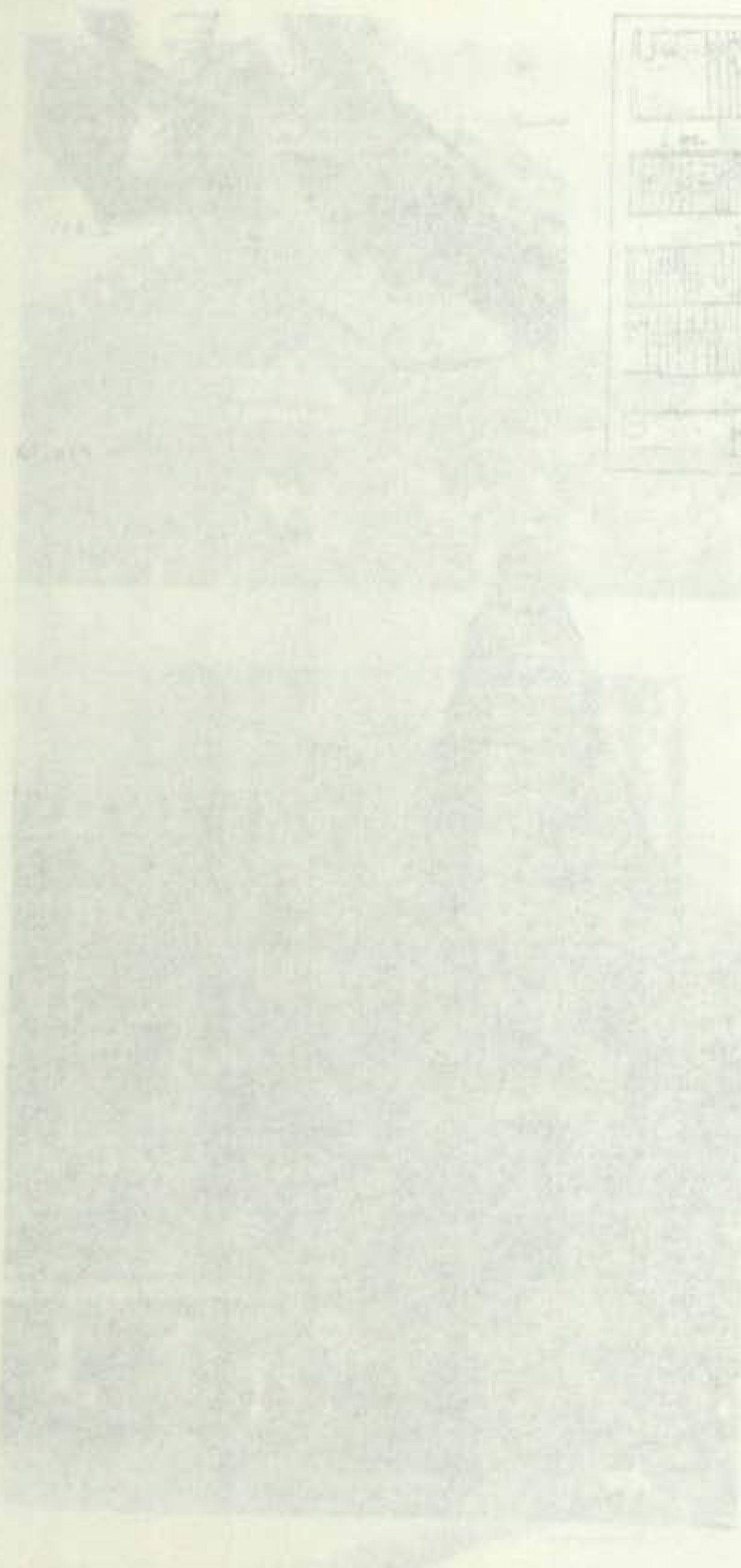

Fig.13
Turning the church around the cen- [illegible] ... into pieces of [illegible]. The [illegible] of the church is made [illegible] by [illegible] which are held in front of the wheels (Fig.12) so that [illegible] changes its direction inch by inch.

Fig.14
After the end of the festival the chariots are dismantled and 'parked' under shelters planted from palmleaves, where they stay till the next Ratha Yatra. On the left a [illegible] can be seen, a pavilion which serves for the ritual 'landing' and boarding of the chariot at the beginning and at the end of the festival.

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PHOTOGRAMMETRIE UND ARCHÄOLOGIE

PHOTOGRAMMETRY AND ARCHAEOLOGY

SUMMARY:
Photogrammetry is a measuring method especially appropriate for archaeological purposes because it has a great number of advantages compared with conventional methods.
The author discusses practical problems with regard to special possibilities of picture taking and picture evaluation made possible by photogrammetry. These possibilities are explained with the help of some examples.

Meine verehrten Damen und Herren,
bei der Vorbereitung dieses Vortrages fiel mir ein kleines Bändchen in die Hände, das vom Luftbild und der Archäologie handelt, so der Titel, herausgegeben in der 2.Auflage 1962 vom Rheinischen Landesmuseum in Bonn im Auftrage des Landschaftsverbandes Rheinland. Der Text stammt von meinem Vorredner, Herrn Dr. Irwin Scollar. Wie der Titel vermuten läßt, wird hier das Luftbild genutzt, um, wie der Untertitel sagt, "Spuren der Vergangenheit im rheinischen Boden" aufzufinden. Sehr verdienstvoll wird hier gezeigt, auf Grund mehrjähriger Erfahrung, welche Schwierigkeiten mit dem "Entdecken von Spuren" verbunden sind. Wir sehen also, daß schon das Luftbild allein für die Archäologie von besonderer Bedeutung ist.

Nun beginnt ja die eigentliche Arbeit des Archäologen mit der Dokumentation der Bodenaltertümer, die Grundlage aller weiteren Arbeiten, nämlich der Interpretation und wissenschaftlichen Deutung, sein muß. Jede Dokumentation beinhaltet aber eine Registrierung aller Einzelheiten in 3 Dimensionen, wobei in Sonderfällen eine Dokumentation in 2 Dimensionen ausreichend sein kann.
Diese Dokumentation geschieht in aller Regel durch eine Vermessung der zu registrierenden Einzelheiten.
Nun ist bekannt, daß eine Vermessung ihre Zeit braucht, besonders dann, wenn eine Fülle von Einzelheiten zu erfassen ist. Zudem müssen diese Vermessungen häufig unter erheblichem Zeitdruck durchgeführt werden, weil Baumaßnahmen oder andere künstliche Eingriffe keinen Zeitaufschub dulden. Hier und genau hier haben die Geodäten ein Mittel in der Hand, die Dokumentation sehr schnell auszuführen, nämlich die Photogrammetrie.

In der mir zur Verfügung stehenden Zeit möchte ich nun einen kurzen Abriß über die Grundlagen und Einsatzmöglichkeiten der Photogrammetrie zur Dokumentation archäologischer Gegenstände geben.
Wir wollen zunächst feststellen, wie die zu archivierenden Objekte selbst aussehen können. Wir teilen sie zweckmäßigerweise nach folgenden Gesichtspunkten ein:

1. Ebene Gebilde:
1.1 horizontal gelagert
1.2 vertikal gelagert
2. Räumliche Gebilde:
2.1 mit geringen Höhenunterschieden (z.B. Mauerreste von Grundmauern)
2.2 mit größeren Höhenunterschieden (z.B. Gebäude in Stockwerkshöhe)
2.3 mit Innenräumen

wenn eine 2.Aufnahme von einem benachbarten Standpunkt aus angefertigt wird.

Nun wird in der Photogrammetrie vom sogenannten stereoskopischen Sehen und Messen Gebrauch gemacht. Bekanntlich vermag der Mensch mit seinem Gehirn die beiden voneinander verschieden aussehenden Bilder auf den Netzhäuten seiner beiden Augen zu einem einzigen Bild, einem räumlichen Bild zu verschmelzen. Dieses natürliche räumliche Sehen wird in der Photogrammetrie künstlich in der Form herbeigeführt, daß man Aufnahmen von 2 verschiedenen Standpunkten den beiden Augen getrennt zuführt, daß also das linke Auge nur das vom linken Standpunkt und das rechte Auge nur das vom rechten Standpunkt gefertigte Bild sieht.
Wenn bestimmte Bedingungen, auf die ich hier nicht eingehen möchte, eingehalten sind, erhält der Betrachter wieder einen räumlichen Eindruck. Wir sagen, es entsteht ein räumliches verkleinertes Modell des abgebildeten Raumes. Bringt man nun in jedem Bild noch eine bewegliche Marke unter, so werden auch diese beiden getrennten Marken zu einer einzigen Raummarke vereinigt, die man durch geeignete Einrichtungen manuell beliebig bewegen kann. Werden diese Einrichtungen noch mit einem Zeichenstift und/oder mit Zählwerken und/oder mit elektronischen Registriereinheiten versehen, ist eine meßtechnische Erfassung des stereoskopisch erzeugten Raummodells möglich. Soweit in aller Kürze das stereoskopische Meßverfahren.

Kommen wir nun zu den eingangs erwähnten räumlichen Gebilden und zu den Verfahren, die sich in aller Regel zur Dokumentation eignen.
Räumliche Gebilde mit geringen Höhenunterschieden lassen sich eventuell durch Einbildmessung, also im Entzerrungsverfahren dokumentieren. Hierbei muß mindestens eine Aufnahme von einem erhöhten Standpunkt, also einem Steiger oder einem Ballon, gefertigt werden, also mit vertikaler Aufnahmeachse. Als Ergebnis erhält man einen entzerrten Bildplan. Das Verfahren unterscheidet sich also nicht von dem für die Dokumentation eines horizontal gelagerten ebenen Gebildes. Sobald jedoch die Höhenunterschiede größer sind, ist das stereoskopische Meßverfahren anzuwenden. Je nach örtlicher Gegebenheit kann sowohl die terrestrische als auch die Luftbild-Photogrammetrie angewandt werden. Beide Verfahren haben ihre Vor- und Nachteile. Meistens wird es so sein, daß beide Verfahren gleichzeitig anzuwenden sich anbieten, da man mit den Luftbildaufnahmen eine Grundriß- und Höhenauswertung erhält, während sich die terrestrische Photogrammetrie zur Ergänzung nicht erfaßter sogenannter toter Räume und zur Auswertung von Fassaden oder vertikal verlaufender Objekte anbietet.

Voraussetzung für die Anwendung des stereoskopischen Meßverfahrens ist, daß beide Bilder sich in einem bestimmten Bereich überdecken. Bei Luftbildaufnahmen sollten mindestens 60% des einen Bildes auch im anderen erfaßt sein, bei terrestrischen Meßbildern werden es auf Grund der besonderen Verhältnisse stets mehr sein.
Bei der Auswahl der Verfahren spielt natürlich die Größe der gewünschten Genauigkeit eine Rolle. Während bei Luftbildaufnahmen der Grundriß sehr genau erhalten wird, die Höhe dagegen die kritische Komponente darstellt, ist dies bei den terrestrischen Aufnahmen umgekehrt. Es ist wichtig zu wissen, daß die Genauigkeit der Lage mit dem Quadrat der Entfernung zum Aufnahmeort abnimmt, während die Genauigkeit der Höhenbestimmung nur proportional der Entfernung abnimmt und genauer als die Grundrißsituation ist. Es läßt sich natürlich jede geforderte Genauigkeit erreichen, doch sinnvoll ist es, nur so genau zu arbeiten, wie es die Aufgabe verlangt. Hier sind stets vorbereitende Gespräche nötig.

In meiner Einteilung der Objekte habe ich auch Innenräume angeführt. Daß hier nur die terrestrische Photogrammetrie anzuwenden ist, liegt auf der Hand. Größe und Gestalt des Innenraumes fordern eventuell unterschiedliche Aufnahmeanord-

nungen, die letzten Endes stets diktiert werden von den örtlichen Gegebenheiten. In aller Regel wird hier der Grundriß zweckmäßig mit den normalen Vermessungsmethoden aufgemessen, während die Wände und Decken mit ihren Struckturen je nach der Tiefenerstreckung (Nischen, räumliche Gliederung) entweder im Einbild- oder im Zweibildverfahren aufzunehmen sind. Bei gewölbten Wänden und Decken bietet sich, wie schon erwähnt, das Orthophotoverfahren an.
Schließlich möchte ich noch darauf hinweisen, daß für die Aufnahme von terrestrischen stereoskopischen Meßbildern die sogenannten Doppelmeßkammern besonders geeignet sind, weil sie im Gegensatz zu dem allgemeinen Fall der Stereophotogrammetrie, bei dem an die gegenseitige Lage der beiden Meßkammern keine Bedingung gestellt wird, mit parallelen Aufnahmeachsen mit fester Basis arbeiten und darum auch einfachere Auswertegeräte benutzt werden können.

Summary translated by C.Müller-Waldeck

IRWIN SCOLLAR
RHEINISCHES LANDESMUSEUM
BONN

DIGITAL IMAGE PROCESSING AND ARCHAEOLOGICAL AIR PHOTOGRAPHY

DIGITALE BILDVERARBEITUNG ARCHÄOLOGISCHER LUFTBILDAUFNAHMEN

ZUSAMMENFASSUNG

Seit über 60 Jahren werden Luftbilder von im Boden befindlichen archäologischen Fundstellen mit handgehaltenen Kameras und gewöhnlichen Schwarz/Weiß- oder Farbfilmen aufgenommen. Diese Fotos werden aus dem Fenster von einfachen Sportflugzeugen gemacht. Die inzwischen vorhandenen über 1 Mill. Aufnahmen in diversen Ländern Nordeuropas bilden eine wertvolle Ergänzung der archäologischen Kenntnisse in diesen Gebieten. Die unter der Erdoberfläche befindlichen Reste erscheinen auf den Fotos als Verfärbungen von Bewuchs oder Boden. Aufnahmen, die über viele Jahre hinweg wiederholt gemacht werden, zeigen die verschiedensten Einzelheiten in Abhängigkeit von Bewuchs und jeweiliger Witterung. Nur eine geometrisch korrigierte Aufnahme, die die Ergebnisse der Überfliegungen vieler Jahre zusammenfaßt, kann die Einzelheiten in einer historisch auswertbaren Gesamtheit zusammenstellen. Die nur schwach auf diesen Fotos erkennbaren Spuren müssen in vielen Fällen verstärkt werden. Das ist mit Hilfe von neuen Computertechniken möglich, die im Rheinischen Landesmuseum Bonn entwickelt wurden. Außerdem ist eine neue Technik der archäologischen Prospektion durch die Raumforschung möglich gemacht worden. Die kleinsten Temperaturunterschiede an der Bodenoberfläche, die durch die unterschiedliche Feuchtigkeit und Wärmeleitfähigkeit der im Boden befindlichen archäologischen Reste entstehen, können kartiert und mit Hilfe des Computers ausgewertet werden.

Since 1924 systematic oblique aerial photography has led to the discovery of tens of thousands of previously unknown archaeological sites in Northern Europe. From 1960 to date flights have been made in the Rheinland by the author and his collaborators, resulting in an archive which now contains over 30,000 pictures. The vast majority of sites were visible only once for a very short period of time as faint changes of colour in growing crops. A few were visible as discolourations of soils with different moisture contents in bare fields. The pictures had to be made at extreme oblique angles to maximize contrast. Most such features can never be seen in conventional vertical mapping photos.

The air photo archive of the Landesmuseum forms an essential part of the documentation related to the protection of field monuments in the Rheinland. The most economical form of protection is to prevent construction or earth moving on a site, but this must be done during the earliest planning phase if claims for

compensation are to be avoided. The air photos must be placed before the authorities with unmistakable clarity and in a form compatible with the base maps 1:5,000 used for most planning purposes.

The pictures were taken with hand held cameras of every imaginable type and format from arbitrary positions over various kinds of terrain, both flat and hilly. Since the sites were seen but once, never to appear again, one must work with the pictures available. Two general kinds of operations are needed before they can be used for site protection purposes. First, image defects must be removed and the archaeological features so enhanced that they can be seen by laymen. Second, a geometrically modified image at the scale of the base map must be supplied. Conventional photogrammetric techniques could be employed for the second operation, but not for the first. The necessity for enhancement of picture quality leads to a choice of digital techniques for the geometric correction as well.

In 1976 the Rheinisches Landesmuseum Bonn acquired what is up to now the only image processing system in an archaeological institution, thanks to the generosity of the Stiftung Volkswagenwerk. In the course of the intervening years, the system has been enlarged by the museum to keep pace with increasing needs. A general configuration plan is shown in Fig.1. Four processors and one display controller are in the system at present, and an additional processor is under construction. A high resolution film scanner and writer provide picture input and output. Processing is monitored on a high resolution colour or black and white display. Pictures are stored on disk during processing, and frequently needed maps are stored in run-length coded form on magnetic tape. The system is also used for inventory work at the Landesmuseum with up to 13 simultaneous users. Large excavations in the field are equipped with portable microprocessor controlled terminals and solid state permanent memory for remote data entry via nearby telephone lines when the memories are full. Other terminals in the museum are used for programming and entry of data either into a field monument data bank or into a finds and inventory data bank. The first is a relational data base system of modern design, modest storage requirements and reasonable search times. The second is a hierarchical data management system with fast access, large storage requirements and extensive query facilities. Four programming languages are available for optimum use depending on application.

The systems' integration, software design and execution of the picture processing system was carried out in-house. Special hardware has also been developed for a number of picture processing tasks. The operating systems of the various machines have been tuned for local requirements. A staff of four, two for software and two for hardware is permanently employed. Maintenance is partly in-house, partly through commercial service contract. Total annual costs including salaries, depreciation, insurance, power, air conditioning etc. is roughly half a million marks. The centre also serves archaeological institutions in other Bundesländer for air photo and other activities. Work has also been routinely carried out for the British, Dutch and French monuments protection services. The equipment is at the disposal of any research institution outside normal working hours at cost and is intensively used by medical and astronomical groups in the Bonn area.

Some typical results are shown in the accompanying plates. Pl.1A shows a low-level oblique picture of a neolithic village (Bandkeramik) which is visible as rows of post holes. There are also some traces of Roman walling on the site. The original picture is slightly blurred due to the movement of the aircraft and contrast is not high. Pl.1B shows the same image after removal of motion blur using an anisotropic linear filtering technique with spatially variant characteristics. One of the neolithic houses has been made visible by histogram

mapping with a shifted mean and higher variance. Pl.2A shows a high-level oblique image of a Roman marching camp, probably constructed for a single night's stop. Pl.2B shows a digital orthophoto obtained directly from the centre of Pl.2A using a simple projective transformation. Interpolation of output raster image points from the input raster was done with a bi-cubic spline approximation to a two-dimensional sinc function in order to preserve sharpness. The scanned map which provided the control points for the transformation was superimposed on the pseudo-vertical image.

Recently we have been experimenting with thermal scanning in the 8-14 micron band. Small differences in heat transfer after an abrupt temperature change reveal ancient field boundaries and some large scale buried archaeological features. One example, processed on our machine, is shown in Pls.3A and 3B. The data was taken in the upper Seine valley in France. A prototype rotating mirror scanner with a resolution of 2 milliradians was used, with a thermal accuracy of .05 degree Celsius. Flight lines were about 10km long and 1km wide, giving about 10 million data points per scan. At the low flying altitude aircraft roll, pitch, and yaw in turbulent weather was considerable. The intertial platform of the scanner was unable to respond quickly enough for full correction, but the platform altitudes and gyroscope data were recorded at the ends of each scan line. In addition, mirror rotation speed, radar and barometric altitude and doppler radar ground speed were noted on the magnetic tape in the aircraft. With this information, the distorted image could be corrcted geometrically as shown, using a predictive tracking algorithm for aircraft movement. Further correction for panorama and calibration was then applied. Enhancement was by means of thresholded median filtering for noise removal without loss of edge sharpness, followed by non-linear adaptive statistical differences for contrast and brightness correction, followed again by mild, low-pass gaussian filtering for residual noise reduction. Total processing time was almost an hour for all of the steps. In 1982 test flights over the Cologne Basin will be carried out with the same equipment.

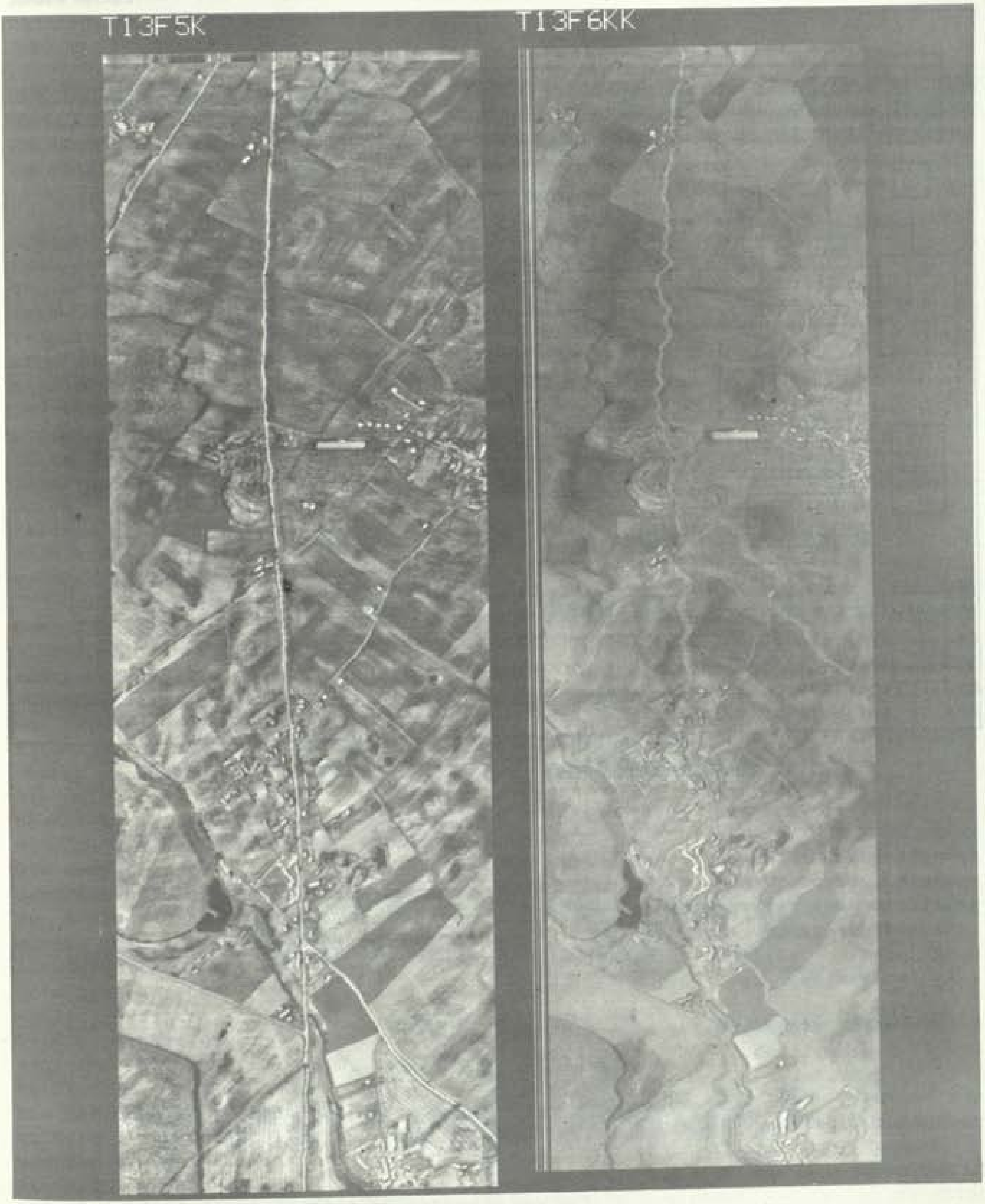
A picture processing installation is a very useful adjunct for an archaeological monuments protection service. In addition, many of the techniques can also be applied to x-ray images of corroded metal objects, to ultra-violet and infra-red images of painted objects, and to any other type of data which can be recorded photographically or on magnetic tape. A large library of enhancement and correction programmes has been written. It is available for the skilled user who has sufficient knowledge of digital picture processing techniques. A few simplified programmes are available via an interactive command language for unskilled users with limited requirements. The software is available on a commercial basis for any interested party under a licensing agreement.

Pl.1A Neolithic village and Roman Walling, Polch (Kr. Mayen), Archive Nr.GH/29; freigegeben Reg.Präs. Düsseldorf, Nr.16/47/8161 (16.6.66)

Pl.1B After processing for motion blur reduction, histogram contrast enhancement

Pl.2A Roman marching camp with claviculi, Menzelen (Kr. Moers), Archive Nr.HF/24; freigegeben Reg.Präs. Düsseldorf, Nr.16/B/52 (26.6.70)

Pl.2B Orthophoto with superimposed 1:5,000 German Base Map of Centre of Pl.2A. Digital Interpolation with bicubic spline approximation to Sinc function following Simon.



Pl.3A and B
Thermal (10.5 micron) infra-red scan in the upper Seine valley, France. Data supplied by Centre de Recherches en Geophysique, Garchy, A.Tabbagh. Area approx. 4x1km, 1m resolution. Roll, pitch and yaw with true ground speed correction, panorama correction, adaptive statistical differentiating contrast enhancement following Wallis, thresholded median filtering noise reduction, linear low pass filtering (gaussian) for residual noise smoothing.

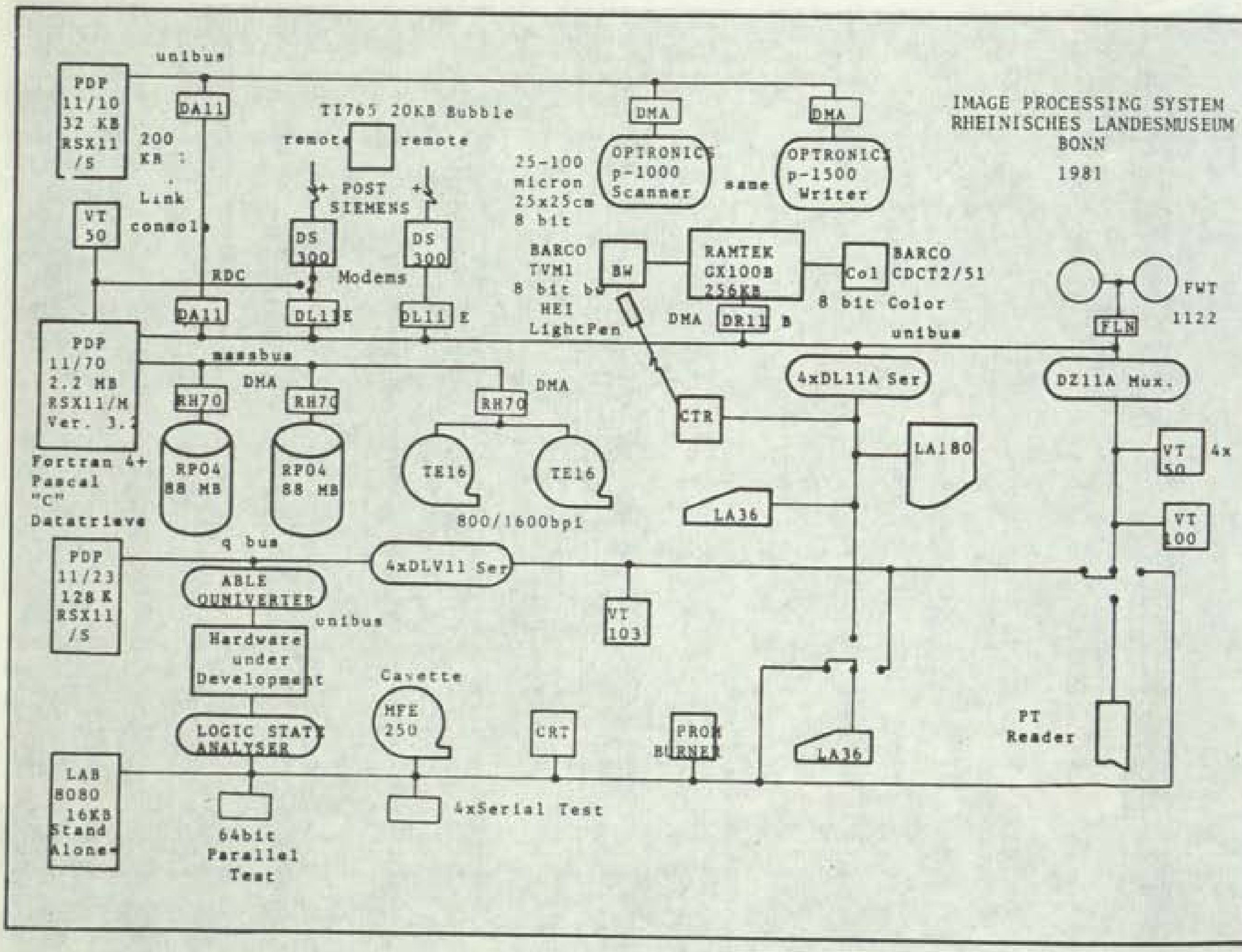


Fig.1 A general configuration plan

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DER HEISSLUFTFESSELBALLON FÜR LUFTAUFNAHMEN IM NAHBEREICH UND ERGEBNISSE MIT DEM ROLLEI SLX-TEILMESSKAMMERSYSTEM

THE USE OF THE TETHERED HOT-AIR BALLOON FOR CLOSE-RANGE AERIAL PHOTOGRAPHY AND RESULTS GAINED WITH THE ROLLEI SLX PARTIALLY CALIBRATED CAMERA SYSTEM

SUMMARY

Experience with the tethered hot-air balloon of the German Mining Museum in documenting surface cultural monuments has proved it to be a robust, relatively easy-to-manage camera vehicle with adequate loading capacity for taking close-range aerial photographs for stereoscopic analysis.
The results of the analysis of building façades photographed with the Rollei SLX partially calibrated camera system also demonstrate the practical possibilities of this photographic system which, due in no small part to its technical refinements (adaptor lens, automatic exposure and film transport), is also suitable for many photogrammetrical operations on the ground.

Der Einsatz von Luftaufnahmen in der Nahbereichsphotogrammetrie scheiterte bisher an der vergleichsweisen Kleinheit der Objekte und den damit verbundenen aufnahmetechnischen Schwierigkeiten, die herkömmliche Meßflugzeuge und Hubschrauber für diesen Zweck unwirtschaftlich werden lassen, einmal abgesehen von flugtechnischen Problemen, die die für den Nahbereich geforderten großen Bildmaßstäbe mit sich bringen. Fernlenkbare Modellflugkörper und Fesselballone bieten sich daher als unbemannte Kameraträger für den Nahbereich an.
Die Einsatztauglichkeit von Modellflugzeugen und Modellhubschraubern wurde bewiesen (vgl. Przybilla et al.; Wester-Ebbinghaus 1980; Summer et al.).

Die komplizierte Technologie solcher Geräte kann einen Einsatz in abgelegenen Gebieten problematisch werden lassen. Auf der Suche nach einem robusten, einfach zu bedienenden Kameraträger für die Aufnahme archäologischer Bodendenkmäler wurden die Anwendungsmöglichkeiten von Fesselballonen näher untersucht. Aerodynamisch, mit Wasserstoff bzw. Helium gefüllte Ballone sind schon erfolgreich für archäologische Zwecke eingesetzt worden (vgl. Lubowski et al.; Whittlesey).
Da die Beschaffung und Handhabung geeigneter Füllgase nicht überall sicher genug möglich ist, wurde im September 1979 mit der Konstruktion eines Heißluftfesselballons begonnen.
Die Ballonhülle besteht aus Synthetikseide und umschließt ein Volumen von ca.200m^3. Der Ballon ist mit Korb ca.11m hoch und hat einen größten Durchmesser von ca.7m (vgl. Heckes).
Die Hülle wird durch zwei Flüssigphasenbrenner beheizt, die über ein Regelventil aus einer 6 KG-Aluminiumflasche versorgt werden.

Am Einsatzort notwendige Aufrüstungsarbeiten (Zusammenbau des Korbes, Befestigung der Kameras, Aufheizen der Hülle) nehmen etwa 30 Minuten in Anspruch. Der Ballon wird dann mit zwei an gegenüberliegenden Stellen des Ballonringes befestigten Seilen unter Beachtung der Windrichtung über den Aufnahmeort rangiert. Ein Schnurlot gibt den gewünschten Aufnahmeabstand an. Nach einiger Übung war es durch die regelbare Beheizung der Hülle einfach, den

Ballon in einer bestimmten Höhe in Gleichgewicht zu halten. Die Dauer, die für die photographischen Aufnahmen zur Verfügung steht, wird im wesentlichen von der zu befördernden Nutzlast und von der Heizleistung des verwendeten Gases bestimmt. Für den Einsatz in Oman ergaben sich Zeiten zwischen 30 Minuten und einer Stunde pro Gasfüllung, die durch Landungen für Filmwechsel unterbrochen wurden. Durch gerade abgeschlossene Umkonstruktionen des Ballonkorbes und der Kameraaufhängungen sowie durch Modifikationen des Brennersystems werden Einsatzzeiten von 1-2 Stunden je Gasfüllung angestrebt.

Als Aufnahmekammer wurde die von Wester-Ebbinghaus (1981) entwickelte Rollei SLX-Teilmeßkammer eingesetzt. Diese Kammer hat motorischen Filmtransport und eine Belichtunsautomatik (Blendenautomat mit Zeitvorwahl), unerläßliche Voraussetzung, wenn Aufnahmen auch bei wechselnden Lichtverhältnissen gelingen sollen. Schwarz/weiß-Rollfilme (220) mittlerer Empfindlichkeit, die mit 1/125 belichtet wurden, haben sich als Aufnahmematerial bewährt.

Der Heißluftballon wurde 1980 und 1981 erfolgreich für die Aufnahme von Bodendenkmälern im Rahmen der montanarchäologischen Expeditionen des Deutschen Bergbau-Museums im Sultanat Oman eingesetzt (vgl. Heckes und Weisgerber 1980 und 1981)
Neben Übersichtsaufnahmen der verschiedensten archäologischen Befunde konnten stereoskopisch auswertbare Meßbilder einer kleinen Burganlage aufgenommen werden, die 1980 vor und 1981 nach der Ausgrabung photographiert werden konnte. Die Abb.2 und 3 zeigen die Burganlage Maysar 25 vor und nach der Ausgrabung.

Die Auswertungen werden am Zeiss Planicomp C113 des Zollern-Institutes (s. Literaturangabe 10) durchgeführt. Über die erzielten Auswertegenauigkeiten geben die beiden Orientierungsprotokolle (Tab.1, 2) Auskunft.
Die Protokolle zeigen, daß mittlere Restabwicklungen von +/-2cm erreicht werden konnten, Genauigkeiten, die für die weiteren Auswertungen (Höhenlinienpläne, graphische Darstellung digitaler Geländemodelle, kartographische Darstellung in Grundriß und Aufriß, Flächen und Volumenangaben) völlig ausreicht.
Bemerkenswert ist noch, daß die angegebenen Punktlagegenauigkeiten ohne Berücksichtigung von Reseauinformationen erzielt werden konnten.

Aufgrund der bei der Auswertung von Ballonaufnahmen erzielten geringen Koordinatenrestfehler, die praktisch in der Größenordnung der Paßpunktbestimmungen liegen, wurde das Teilmeßkammersystem Rollei SLX auch bei der Aufnahme von Gebäudefassaden eingesetzt.
Im Rahmen eines Projektes zur Dokumentation der Malakofftürme des Ruhrgebietes konnten bisher Aufnahmen von Fassaden der Malakofftürme Julius Philipp in Bochum und Alte Haase in Sprockhövel ausgewertet werden (Abb.4, 5).
Die Paßpunkte wurden durch räumliche Vorwärtsschnitte bestimmt. Die dabei erreichten Punktlagefehler liegen im Mittel bei +/-7mm. Die Orientierungsprotokolle (Tab.3, 4) zeigen auch hier, daß mit der Rollei SLX-Teilmeßkammer ein mittlerer Koordinatenrestfehler von ca. +/-1cm für Punktmessungen erzielt werden konnte, ein Ergebnis, das für die kartographische Darstellung von Gebäudefassaden völlig ausreicht.

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Summary translated by Dr.M.Mulloy

Abb.1 Der Heißluftballon des Deutschen Bergbau-Museums beim Einsatz im Sultanat Oman
(The German Mining Museum's hot-air balloon in action in the Sultanate of Oman)

Abb.2 Maysar 25 vor der Ausgrabung
(Maysar 25 before excavation)

Abb.3 Maysar 25 nach der Ausgrabung
(Maysar 25 after excavation)

Abb.4 Malakofftrum Julius Philipp in Bochum-Wiemelhausen
(Malakoff Tower Julius Philipp in Bochum-Wiemelhausen)

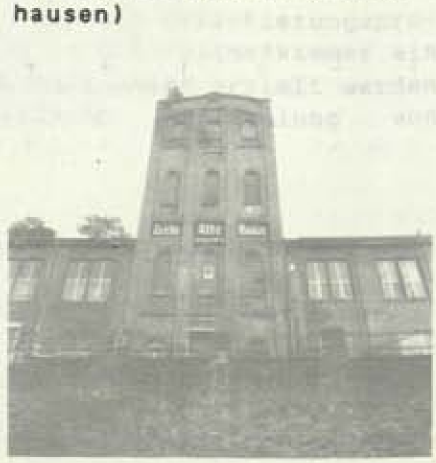

Abb.5 Malakoffturm Alte Haase in Sprockhövel
(Malakoff Tower Alte Haase in Sprockhövel)

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MODELL OM005BAN 80033 07/06 AUSWERTER J. HECKES  DATUM 1982. 2. 8.12.48
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 MODELLMASSTAB 1:   1000  TISCHMASSTAB 1:    100 BILDMASSTAB 1:   1593

 ORIENT.DATEN       BILD LINKS  BILD RECHTS                       MODELL
 ------------
              F       40.000      40.000   FLUGHOEHE                  62
          OMEGA        3.913       6.190   UEBER GRUND
            PHI        -.825      -3.722
          KAPPA        4.247        .645              AZIMUT       3.768
             BX       -1.729       1.729   LAGE DES( XG0         9336.47
             BY        2.195      -2.195   MODELL  ( YG0         9353.96
             BZ         .366        .366   ZENTRUMS( ZG0          566.07

 MOD.BASIS: B =      5.636 (ORTHO)     ERDKRUEMM.KORR.: R =     6370000

 ORIENTIERUNGS-PROTOKOLL
 -----------------------
 ABSOLUTE ORIENT.  PASSPUNKTE                 LAGE  6    HOEHE  5
                   PUNKT NO.          219005          218      218007
                   PUNKT NO.          218004       218003      218005
                   KOORDINATEN RESTFEHLER          MITTEL         MAX
                                              X      .019        .033
                                              Y      .018       -.025
                                              Z      .016        .025

 RELATIVE ORIENT.  PARALLAXENPUNKTE      21
                   RESTPARALLAXEN            MITTEL   .003  MAX   .005

 INNERE ORIENT.    VERW. RAHMENMARKEN   1234               LINKS   RECHTS
                                        X-SCHRUMPF      .998929  .999022
                                        Y-SCHRUMPF      .999083  .999297
                                        RECHTWINKL.      .00002   .00008
```

Tab.1 Burganlage M-25 vor der Grabung; Orientierungsprotokoll (Fortress M-25 before excavation; orientation protocol)

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MODELL OM004BAP 81032 02/07 AUSWERTER J. HECKES  DATUM 1982. 2. 8.12.48
------------------------------------------------------------------------

 MODELLMASSTAB 1:   1000  TISCHMASSTAB 1:     50 BILDMASSTAB 1:   1067

 ORIENT.DATEN       BILD LINKS  BILD RECHTS                       MODELL
 ------------
              F       40.000      40.000   FLUGHOEHE                  42
          OMEGA       -1.928       -.157   UEBER GRUND
            PHI        -.995       -.437
          KAPPA        2.754      -1.907              AZIMUT     -77.728
             BX       -6.097       6.097   LAGE DES( XG0         9330.01
             BY         .011       -.011   MODELL  ( YG0         9373.49
             BZ         .714       -.714   ZENTRUMS( ZG0          548.23

 MOD.BASIS: B =     12.277 (ORTHO)     ERDKRUEMM.KORR.: R =     6370000

 ORIENTIERUNGS-PROTOKOLL
 -----------------------
 ABSOLUTE ORIENT.  PASSPUNKTE                 LAGE 14    HOEHE 13
                   PUNKT NO.             412          459         456
                   PUNKT NO.             402          461         408
                   PUNKT NO.             407          411         403
                   PUNKT NO.             404          405         406
                   PUNKT NO.             410          462
                   KOORDINATEN RESTFEHLER          MITTEL         MAX
                                              X      .012        .025
                                              Y      .015        .027
                                              Z      .010        .024

 RELATIVE ORIENT.  PARALLAXENPUNKTE      23
                   RESTPARALLAXEN            MITTEL   .002  MAX  -.005

 INNERE ORIENT.    VERW. RAHMENMARKEN   1200               LINKS    RECHTS
                                        X-SCHRUMPF    1.002708  1.002503
                                        Y-SCHRUMPF    1.002703  1.002503
                                        RECHTWINKL.    0.00000   0.00000
```

Tab.2 Burganlage M-25 nach der Grabung; Orientierungsprotokoll (Fortress M-25 after excavation; orientation protocol)

Tab.3 Malakoffturm Julius Philipp; Orientierungsprotokoll
(Malakoff Tower Julius Philipp; orientation protocol)

MODELL MT001CAN80 4201/4207 AUSWERTER J. HECKES DATUM 1982. 2. 8.12.42

MODELLMASSTAB 1: 1000 TISCHMASSTAB 1: 50 BILDMASSTAB 1: 799

ORIENT.DATEN	BILD LINKS	BILD RECHTS		MODELL
F	40.000	40.000	FLUGHOEHE UEBER GRUND	28
OMEGA	19.017	16.429		
PHI	-.527	1.680		
KAPPA	-2.153	-2.218	AZIMUT	1.928
BX	-2.927	2.927	LAGE DES(XG0	109.04
BY	.023	-.023	MODELL (YG0	101.63
BZ	-.332	.332	ZENTRUMS(ZG0	-71.38

MOD.BASIS: B = 5.892 (ORTHO) ERDKRUEMM.KORR.: R = 6370000

ORIENTIERUNGS-PROTOKOLL

ABSOLUTE ORIENT. PASSPUNKTE LAGE 6 HOEHE 6

PUNKT NO.	101	102	103
PUNKT NO.	104	105	106

KOORDINATEN RESTFEHLER	MITTEL	MAX
X	.006	.008
Y	.009	-.016
Z	.013	-.022

RELATIVE ORIENT. PARALLAXENPUNKTE 20
RESTPARALLAXEN MITTEL .003 MAX -.005

INNERE ORIENT. VERW. RAHMENMARKEN 1200

	LINKS	RECHTS
X-SCHRUMPF	.999676	.999390
Y-SCHRUMPF	.999676	.999390
RECHTWINKL.	0.00000	0.00000

Tab.4 Malakoffturm Alte Haase; Orientierungsprotokoll
(Malakoff Tower Alte Haase; orientation protocol)

MODELL MT002TAN81 107 02/12 AUSWERTER J. HECKES DATUM 1982. 2. 8.12.43

MODELLMASSTAB 1: 1000 TISCHMASSTAB 1: 50 BILDMASSTAB 1: 644

ORIENT.DATEN	BILD LINKS	BILD RECHTS		MODELL
F	40.000	40.000	FLUGHOEHE UEBER GRUND	-16
OMEGA	133.028	133.723		
PHI	-5.902	-6.825		
KAPPA	3.042	3.954	AZIMUT	8.881
BX	-4.512	4.512	LAGE DES(XG0	126.85
BY	.247	-.247	MODELL (YG0	100.66
BZ	.000	-.000	ZENTRUMS(ZG0	100.03

MOD.BASIS: B = 9.038 (ORTHO) ERDKRUEMM.KORR.: R = 6370000

ORIENTIERUNGS-PROTOKOLL

ABSOLUTE ORIENT. PASSPUNKTE LAGE 10 HOEHE 10

PUNKT NO.	104	103	108
PUNKT NO.	105	106	109
PUNKT NO.	101	102	111
PUNKT NO.	113		

KOORDINATEN RESTFEHLER	MITTEL	MAX
X	.005	-.009
Y	.004	-.007
Z	.006	.009

RELATIVE ORIENT. PARALLAXENPUNKTE 14
RESTPARALLAXEN MITTEL .003 MAX -.005

INNERE ORIENT. VERW. RAHMENMARKEN 1234

	LINKS	RECHTS
X-SCHRUMPF	1.000008	.999643
Y-SCHRUMPF	.999770	1.000037
RECHTWINKL.	.00011	.00030

KARL LUDWIG BUSEMEYER
GEFA-FLUG AACHEN

EINIGE GEDANKEN ZUM EINSATZ VON FERNEGELENKTEN BALLONEN UND LUFTSCHIFFEN ZUR LUFTBILDERSTELLUNG

SOME THOUGHTS CONCERNING THE USE OF REMOTE-CONTROLLED BALLOONS AND AIRSHIPS FOR THE PRODUCTION OF AERIAL PHOTOGRAPHS

SUMMARY

A historical outline of the use of balloons and airships for scientific purposes and a prospect of a possible revival for these purposes.
Discussion of the possibilities of using the remote-controlled aerostatic systems of flight for the production of aerial photography.
Description of a newly developed remote-controlled type of airship (hot-air balloon) to be used for close-range aerial photography and its peculiarities.
Prospects for further improvements of the type of airship described.

Die Ballonfahrt hatte ihre Geburtsstunde im Jahre 1783, die Photographie einige Zeit später. Bereits in der Mitte des vergangenen Jahrhunderts wurden von Ballonen aus die ersten Luftbilder erstellt (Nadar in Paris). Auch die Erdkrümmung wurde photographisch zu Beginn des 20. Jahrhunderts von Bord eines Ballones dokumentiert (Dahl in Wuppertal).
Die Entwicklung von Luftschiffen erschlossen neue Möglichkeiten der Luftbilderstellung. Bekannte Beispiele sind die Arktisfahrten des Italieners Nobile in den 20er Jahren und die mehrtägige Arktisfahrt des Luftschiffes "Graf Zeppelin" im Jahre 1931. Weite Gebiete der Polargegend sind mit eigens hierfür entwickelten Kamerasystemen erforscht und teilweise erst entdeckt worden.

Die rasante Entwicklung von Flugsystemen "Schwerer als Luft" - Flugzeugen also - boten weitere Möglichkeiten und dominieren heute das Feld bei der Luftbilderstellung.
Seit einigen Jahren wird verstärkt an neuen Ballon- und Luftschiffprojekten gearbeitet und in Marktnischen eingesetzt, die von konventionellen Luftbilderstellungsmethoden nicht bearbeitet werden können.
Dafür gibt es folgende Gründe:
zum einen ist herkömmliche Luftbilderstellung ein sehr teures Verfahren und erfordert zudem den Einsatz komplizierter Technologien,
zum anderen gibt es bei herkömmlichen Methoden Schwierigkeiten unter einen Bildmaßstab von 1:1500 zu kommen; dies stellt aber für bestimmte Aufgaben - wie z.B. bei archäologischer Feldarbeit - eine sinnvolle Ergänzung dar.

In den 60er Jahrenn kam es weltweit zu einer Renaissance des Heißluftballonsports, ermöglicht durch leichte, schwer entflammbare Kunststofftextilien als Hüllenmaterialien und hochenergetischem Flüssiggas als Heizquelle. Im Gefolge dieser Renaissance entwickelte sich auch im Modellbau ein neuer Zweig, der sich mit der Konstruktion von ferngelenkten Ballonen und Luftschiffen beschäftigt.

Eine Möglichkeit der kommerziellen Anwendung solcher Modelle besteht in der Verwendung als "luftige" Kameraplattform. Verschiedene Typen sind dabei zu unterscheiden:

BALLONE UND LUFTSCHIFFE

Der Unterschied zwischen Ballon und Luftschiff liegt in der Form begründet; Ballone besitzen einen entsprechend ihrem Durchmesser sehr hohen Windwiderstand und sind daher nur bei geringen Windgeschwindigkeiten einsetzbar. Luftschiffe sind aerodynamisch durchgebildete Flugkörper; dies bedingt einen erheblich geringeren Luftwiderstand. Zusätzlich besitzen Luftschiffe einen Antrieb zur gezielten Vorwärtsbewegung; dies soll aber in der weiteren Betrachtung hier keine Rolle spielen.

KALTE UND HEISSE SYSTEME

Des weiteren muß bei Flugsystemen "Leichter als Luft" zwischen verschiedenen Auftriebsmedien unterschieden werden: zwischen einer Gasfüllung mit Wasserstoff oder Helium (kaltes System) oder einer Verdünnung des Volumens durch Erwärmung (heißes System).
Beide Systeme haben verschiedene Vor- und Nachteile, für die aber hier nicht der Platz ist sie aufzuzeigen.
Wichtiger Vorteil des heißen Systems ist die weltweite Verfügbarkeit von Flüssigheizgas. Wasserstoff und Helium sind weltweit nur unter Schwierigkeiten verfügbar und zudem nur in schweren Stahlflaschen erhältlich.

Seit 1975 beschäftige ich mich mit mehreren Freunden intensiv mit dem Bau und dem Einsatz von ferngelenkten Ballonen und Luftschiffen. 1980 bildeten wir unsere Arbeitsgemeinschaft um in die "Gesellschaft zur Entwicklung und Förderung Aerostatischer Flugsysteme mbH", deren Zielsetzung es ist, Ballone und Luftschiffe zur Luftbilderstellung und Luftschichtenanalyse zu konzipieren und einzusetzen.
1981 brachte ein mit einer Super 8 Kamera ausgerüstetes Luftschiff bei einem vierzehntägigen Aufenthalt bei der BBC in Bristol/Großbritannien die ersten brauchbaren Ergebnisse, die in Abstimmung mit der besonderen Aufgabenstellung in Mohenjo-Daro zu folgender Projektdefinition führte:

HEISSLUFTSCHIFF GFL 145

Das System stellt insoweit eine Novität dar, als hier wohl zum ersten Mal versucht wurde, die aerodynamisch günstige Luftschifform beim Heißluftsystem zu verwenden. Auf Grund niedriger Innendrücke können hier allerdings nur Längen Durchmesser Verhältnisse von max.2.5:1 erzielt werden, außerdem kannn eine optimale Temperaturverteilung bei größeren Streckungen (auf einfache Weise) nicht realisiert werden, so daß es zu Trimmschwierigkeiten käme.

Technische Daten: Länge 11.5 Meter, Durchmesser 5.0 Meter, Volumen 145m^3, Auftrieb durch Erwärmung des Füllvolumens mittels Flüssigphasen, Doppelbrenner mit einer Gesamtleistung von 15.0000 kcal/h. Gasverbrauch pro Stunde etwa 6kg (Abb.1).
Die Luftschiffhülle besteht aus 19 Längssegmenten eines kunststoffbeschichteten Nylongewebes "Polyant Airship" von Verseidag, wie es auch zum Bau bemannter Ballone Verwendung findet. Das Gewebe ist temperaturfest bis 121°C. Der Gesamtauftrieb des Luftschiffes beträgt 50 kg bei 15°C und 760 mbr.
Die Fernlenkanlage ist eine Industriesteuerung von Brandel-Elektronik und arbeitet im 443 MHZ Band. Insgesamt fünf Funktionen werden mittels dieser Anlage gesteuert: Pliotbrenner, 2 Hauptbrenner, Kameradrehvorrichtung und Kameraauslösung.

Zur Kameradrehvorrichtung: um definierte Flugstreifen anfertigen zu können, besteht die Möglichkeit, die Kamera per Fernsteuerung zu drehen.
Ein Zeiger, am Ballonkorb montiert und mittels drehbarer Welle mit der Kamera gekoppelt, ermöglicht das Beobachten der jeweiligen Kamerastellung mit genügender Genauigkeit (Abb.2).

Der hier beschriebene Luftschifftyp wurde in einer mehrtägigen Testphase im Sommer 1982 auf Gut Breitenstein/Aachen ausführlich erprobt und erfüllte die in ihn gesetzten Erwartungen. Die Positionierung mittels der Halteleinen stellt bei genügend freiem Gelände kein Problem dar, die Höhenstaffelung mittels einer Lotleine arbeitet ebenfalls zufriedenstellend.

Für die Zukunft wird über die Kopplung der Drehvorrichtung mit einer Kreiselsteuerung nachgedacht, so daß eine einmal gewählte Ausrichtung der Kamera selbständig eingehalten wird. Des weiteren ist das Mitführen einer Videokamera an Bord geplant, um ein schnelleres Positionieren des Gerätes über einem bestimmten Punkt zu ermöglichen. Beide Punkte erfordern allerdings einen auf 200 m^3 vergrößerten Luftschifftyp mit einer freien Tragkraft von etwa 30 kg.

VOR- UND NACHTEILE

Vorteile einer wie auch immer gearteten Ballon- oder Luftschiffkonstruktion sind die ständige Verfügbarkeit bei Feldarbeiten und die spontanen Einsatzmöglichkeiten. Aufrüstungszeiten liegen bei weniger als 30 Minuten.
Ein weiterer Vorteil ist die Einfachheit und Robustheit der Systeme, notwendige Reparatur- und Wartungsarbeiten können auch vor Ort durchgeführt werden.
Lediglich der Pilot benötigt eine hohe Qualifizierung, als weitere Mannschaft kann Hilfspersonal eingesetzt werden. Nach wenigen Einsätzen ist das Personal genügend geschult (Abb.3).
Nachteile stellen die Halteseile dar, die einen Einsatz über bebautem oder stark bewachsenem Gebiet erschweren. In jedem Fall sollte das zu dokumentierende Terrain oder Objekt von allen Seiten begehbar sein.
Haupteinschränkung eines Ballon- oder Luftschiffsystems ist die relative Wetterabhängigkeit. Der Einsatz verlangt gute Witterungsbedingungen mit niedrigen Windgeschwindigkeiten. Dieses Faktum dürfte einem Einsatz "auf Bestellung" im Wege stehen.

RESUMEE

Zieht man als eigentlichen Nachteil die Wetterabhängigkeit in Betracht und kalkuliert bei Prjektplanungen etwaige Wartezeiten mit ein, so steht mit einem wie hier beschriebenen System ein preisweter Kameraträger zur Verfügung, der neue Möglichkeiten bietet, einfach und robust in der Handhabung ist und quasi "aus dem Koffer" betrieben werden kann.
Sicherlich wird der praktische Einsatz in Mohenjo-Daro noch eine Vielzahl von Aspekten aufzeigen, und man wird erst nach Abschluß dieses ersten Einsatzes ein wirkliches Resumee ziehen können; diese Erfahrungen werden in die Konstruktion und den Bau weiterer Systeme fließen.

Der interessierte Leser sei an dieser Stelle auf weiterführende Fachliteratur in dem Buch "RC-Luftschiffe und Ballone" von K. L. Busemeyer, Neckar Verlag, hingewiesen.
Ich möchte an dieser Stelle der Deutschen Forschungsgemeinschaft und Herrn Dr. Jansen vom Forschungsprojekt Mohenjo-Daro dafür danken, daß der Bau und der Einsatz eines Luftschiffes zur Luftbilderstellung in Mohenjo-Daro möglich wurden.

Summary translated by C.Müller-Waldeck

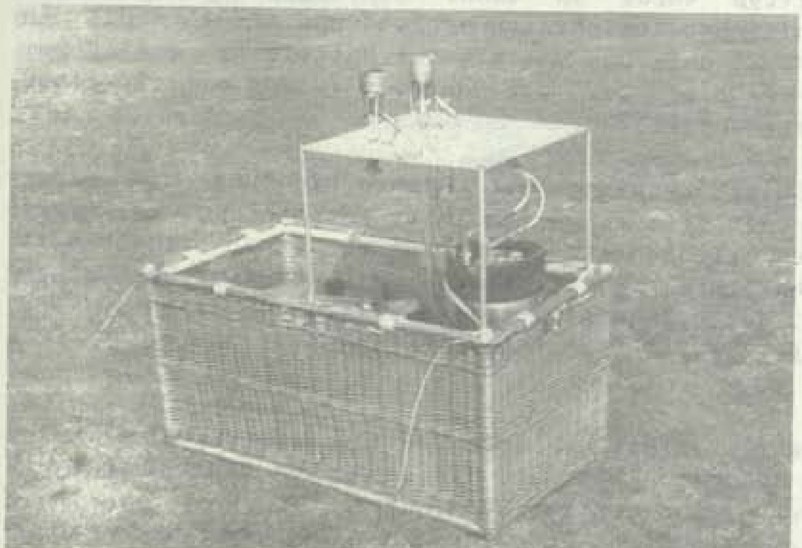

Abb.1
Die Luftschiffgondel mit Doppelbrenneranlage

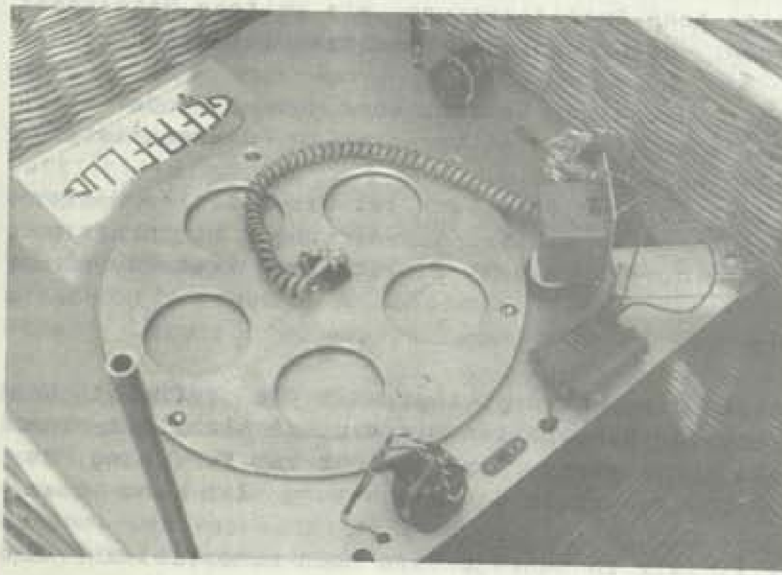

Abb.2
Blick in die Gondel auf die Kameradrehvorrichtung und Fernlenkanlage

Abb.3 Das Luftschiff nach dem Aufstieg

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ZERSTÖRUNG VON ZIEGELN DURCH SALZE

THE DESTRUCTIVE EFFECTS OF SALTS ON BRICKS

SUMMARY

The brick material was very lightly fired. In texture it is highly porous, loose and very heterogeneous. Relatively large particles of calcium sulphate already present in the clay were incorporated into the finished bricks. At higher firing temperatures of approx. 1,000 ^{o}C quicklime can form which, as a result of secondary hydration, can lead to the desintegration of the bricks. Similarily Na_2O may also have been present in the original brick clay. The crystallization pressure produced by the transformation of thenardit into mirabilit can greatly accelerate the destruction of the bricks.
For their active help in interpreting the experiment results at such short notice I would especially like to thank Herrn Dipl.-Min.Th.Koslowski and Herrn Akad.Dir.Dr.-Ing.W.-G.Burchard.

Normalerweise wird man unter den heutigen Produktionsbedingungen kaum mit einer Zerstörung von Ziegeln durch Salze rechnen können. Einmal ist der Gehalt löslicher Salze in Ziegeln gering und zum anderen werden die Ziegelmaterialien hoch genug gebrannt, wobei die Salze weitgehend in die glasig-amorphe Matrix des Ziegelgefüges eingelagert werden. Wohl bekannt dagegen sind auch heute noch unschöne Ausblühungen an Sichtmauerwerken aus Ziegeln. Auch an Dachziegeln werden Ausblühungen an der Dachunterseite beobachtet. Diese Ausblühungen werden jedoch bereits durch Bruchteile von <1% ausblühfähiger Salze erzeugt. Sie treten vornehmlich in den Übergangsjahreszeiten zum Winter und zum Sommer hin auf, wenn die Luftfeuchtigkeit hoch ist und die Verdunstung der flüssigen Phase an der Oberfläche des Mauerwerks erfolgt.
Bei der Behandlung des gestellten Themas muß man gleichermaßen die Ziegelherstellung selbst und die Umweltbedingungen einschließlich der Verarbeitung der Ziegel im Bauwerk berücksichtigen.

Ziegelherstellung	
Verfahrensparameter	Eigenschaften
Rohstoffzusammensetzung Homogenisierung Formgebung Brenntemperatur -dauer und -atmosphäre	Gefüge Festigkeit sonst. Eigenschaften lösliche Salze

Tab.1 Verfahrensparameter und Eigenschaften bei der Ziegelherstellung

Bei der Herstellung der Ziegel interessieren insbesondere die Zusammensetzung der Rohstoffe, die Homogenisierung, die Formgebung und die Brennbedingungen als maßgebliche Verfahrensparameter. Die Eigenschaften des Fertigproduktes lassen sich weitgehend aus den Gefügeparametern: Gesamtporosität, offene Porosität, Porenverteilung und dem Aufbau und der Verteilung der festen Phasen ableiten. Die Gefügeparameter bestimmen neben den mechanischen Eigenschaften das Ausmaß möglicher Transportvorgänge, die zu Beeinträchtigungen von Sichtmauerwerk in einsicht auf die Ästhetik wie auch im vorliegenden Fall sogar auf die Dauerhaftigkeit führen. Zusätzlich ist die Frage zu klären, ob und in welchem Ausmaß lösliche Salze, meistens Alkali- und Erdalkalisalze von Sulfaten, Carbonaten, Nitraten und Chloriden im Baustoff enthalten sind.

Weitere Parameter sind in diesem Zusammenhang die Bauwerksisolierung in Verbindung mit der Lage des Grundwassers, der verwendete Mauer- und Putzmörtel und die Klimatologie: Niederschlag, Feuchte und Temperatur. Es ist selbstverständlich, daß diese Parameter die Durchfeuchtung und die Verdunstungszone beeinflussen.

UNTERSUCHUNGSMETHODEN

Wir sind der Ansicht, daß die Methode zur Kennzeichnung der Eigenschaften von Baustoffen gleichermaßen für alte und neue Materialien einzusetzen sind. Beispiele üblicher Verfahren sind:

Verfahren	Zielgröße
Wasseraufnahme	offene Porosität
Dichte - Rohdichte	Gesamtporosität
Quecksilberdruckporosimetrie	Porenverteilung
Elektronenmikroskopie mit RMA	Gefüge- und Phasenanalyse
Röntgenbeugungsanalyse	Phasenanalyse
Röntgenfluoreszenzanalyse	Chemische Analyse
Mikroskopie Thermoanalyse Erhitzungsmikroskopie Dilatometrie	Phasenanalyse und thermische Verhalten

Tab.2 Beispiele von Untersuchungsverfahren und Ziegelgrößen

Diese Verfahren müssen häufig für die Lösung bestimmter Problemstellungen modifiziert werden.

UNTERSUCHUNGSMATERIAL

Für unsere Bearbeitung des Problems standen folgende Materialien zur Verfügung:

- Ziegelbruchstück
- Mörtel zwischen Lehmziegeln
- Sinterschicht auf Ziegel
- Salzausblühungen

Selbstverständlich war es nicht möglich, die zur Klärung der Fragen erforderlichen Untersuchungen durchzuführen. Vielmehr wurden einige orientierende Untersuchungen beispielhaft durchgeführt, um das Problem der Ziegelkorrosion durch Salzeinwirkung in Verbindung mit dem derzeitigen Kenntnisstand andiskutieren zu können.

An den bereitgestellten Materialien wurden folgende Untersuchungen durchgeführt:

Material	Untersuchung
Ziegel	Makrogefüge am Sägeschnitt " mit Ausblühungen nach 2 Tagen Porosität Mikrogefüge Phasenanalyse Dilatometrie Auslaugung
Mörtel, Sinter und Ausblühung	Mikrogefüge Phasenanalyse

Tab.3 Versuchsmaterialien und durchgeführte Untersuchungen

Das Makrogefüge der Ziegel wird bereits am Sägeschnitt deutlich. Eine innere dunkelrote Zone, ein hellerer äußerer Saum und gröbere Spalten und Klüfte werden klar erkennbar. Zwei Tage nach der Herstellung des Trennschnittes zeigen sie weiße Ausblühungen ausgehend von Rand der Probe auf der Oberfläche.

Die Gesamtporosität handgeformter Massen ist neben der Rohstoffzusammensetzung durch das Formgebunsverfahren höher als bei heutigen maschinellen Verfahren und beträgt 44 Vol.-%. Vergleichungswerte heutiger Produkte liegen im Bereich von 17 Vol.-% für Vormauerqualitäten, bis zu 37 Vol.-% für Untermauerqualitäten und bis zu 46 Vol.-% für porosierte Hintermauerqualitäten für die Scherbenporosität (vgl. Schwiete/Ludwig 1969).

Das Mikrogefüge des Ziegels ist beispielhaft in Abb.1 und in Besonderheiten in späteren Abbildungen dargestellt.

Die REM-Aufnahmen in Abb.1 zeigen ein ausgeprägtes Makroporengefüge. In stärkeren Vergrößerungen ist die geringe Versinterung an den scharf ausgebildeten Ecken und Kanten der ursprünglichen Morphologie der Rohstoffe neben der geringen Versinterung der Einzelpartikel kenntlich.

Dilatometeruntersuchungen zeigen $\geq 700^{\circ}C$ eine stärkere Schwindung des Materials und könnten ein Hinweis sein, daß hier die Brenntemperatur gelegen haben kann. Die chemische Zusammensetzung wurde mit Hilfe der RFA ermittelt:

	GV	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	SO_3	K_2O	Na_2O	Cl
Kern	3.0	59.9	17.5	0.7	5.2	9.2	0.9	2.3	2.4	0.13
Rand	3.5	50.7	17.0	0.6	4.4	9.7	0.8	2.2	2.4	0.15

Tab.4 Chemische Analysen von Rand- und Kernzone des Ziegels

In Tab.5 sind die Anteile auslaugbarer Salze und deren Zusammensetzung angegeben.

	Auslaugung (M.-%)	CaO	MgO	Na_2O	K_2O	SO_3	Cl
		(mg/100ml)					
Kern	7.8	7.4	0.12	14.5	3.5	3.2	6.5
Rand	20.3	4.5	0.08	3.0	1.5	21.3	1.1

Tab.5 Auslaugungen und Zusammensetzung der ausgelaugten Salze

Der Mörtel, der sich zwischen Lehmziegeln befand, ist in Abb.9 dargestellt und besteht weitgehend aus Gips mit gerichtetem Wachstum; daneben ist aber auch mit Salzausblühungen nach dem Analysenbefund zu rechnen. Das Röntgenbeugungsdiagramm wiest entsprechend die Interferenzen des Gips und des Mirabilit (auch Glaubersalz) aus (Abb.10).

Der Sinter von der Ziegeloberfläche ist in Bild 11 wiedergegeben. Er weist ein recht dichtes Gefüge auf und ist vornehmlich aus den Elementen Schwefel, Calcium, Kalium, Natrium, Silicium, Aluminium und Eisen aufgebaut. Seine mineralische Zusammensetzung weist überraschend Halbhydrat neben Dihydrat und Anhydrit u. a. aus (Abb.12).

Die Salzausblühungen sind in Bild 13 wiedergegeben und bestehen chemisch aus Natriumsulfat. Als Mineralphasen werden Thenardit und Mirabilit nachgewiesen (Abb.14). Thenardit ist das wasserfreie Salz, während der Mirabilit unter Aufnahme von 10 Molen H_2O und Volumenzunahme von 300% gebildet wird. Der maximale Kristallisationsdrück ergibt sich nach Knacke und von Erdberg (vgl. Knacke/v.Erdberg 1975) aus thermodynamischen Überlegungen bei Raumtemperatur zu 20 N/mm und nimmt zum Tripelpunkt Thenardit-Mirabilit bei 32°, $38^{\circ}C$ hin auf Null ab (Abb.15). Experimentell wurden bisher als maximaler Druck nur 2 N/mm erreicht. Das System Thenardit-Mirabilit-Lösung ist in Abb.16 dargestellt.

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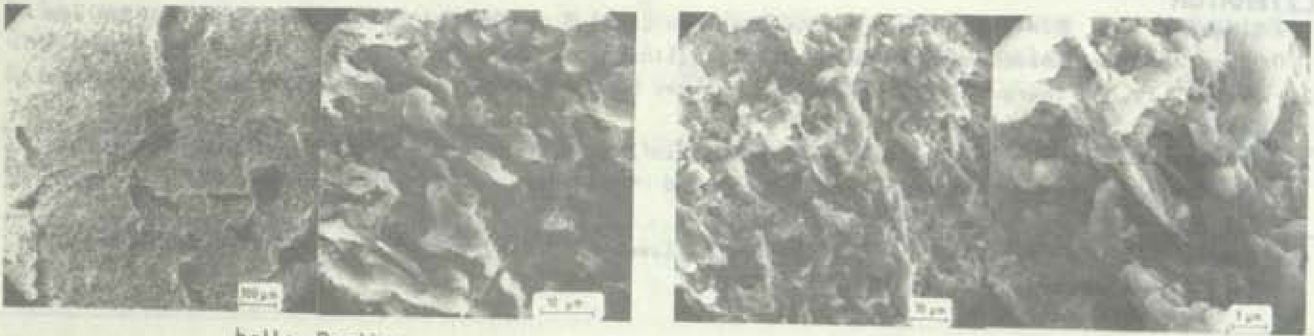
Summary translated by Dr.M.Mulloy



helle Partien dunkle Partien

Abb.1 Ziegelgefüge

Vergleichsweise zeigen die Bilder 2 und 3 REM-Aufnahmen und makroskopische Abbildungen von dichten und porösen Hochbauziegeln. Die Gefügebilder sprechen für sich.

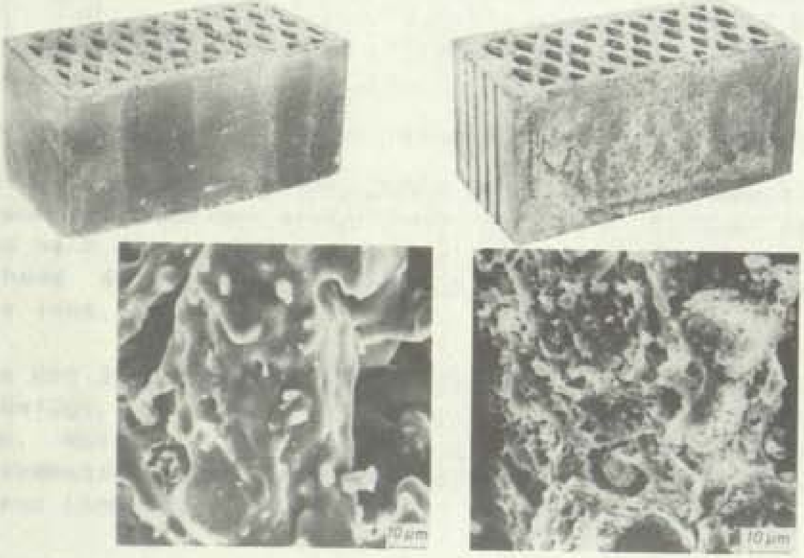


Abb.2 und 3 Dichte und poröse Hochbauziegel

Zu den Gefügen wurden seinerzeit (vgl. Schwiete/Ludwig 1969) auch die Porenverteilungen gemessen und man erkennt für das stark versinterte Material HLz 3 die geringere Gesamtporosität von 12 Vol.-% bei im wesentlichen groben Poren und die hohe Porosität für das schwach gebrannte Material HLz 5 bei breitem Porenspektrum (Abb.4). Dabei ist zu berücksichtigen, daß ein breites Porenspektrum sowohl das kapillare Saugvermögen als auch das Wasserrückhaltevermögen begünstigt.

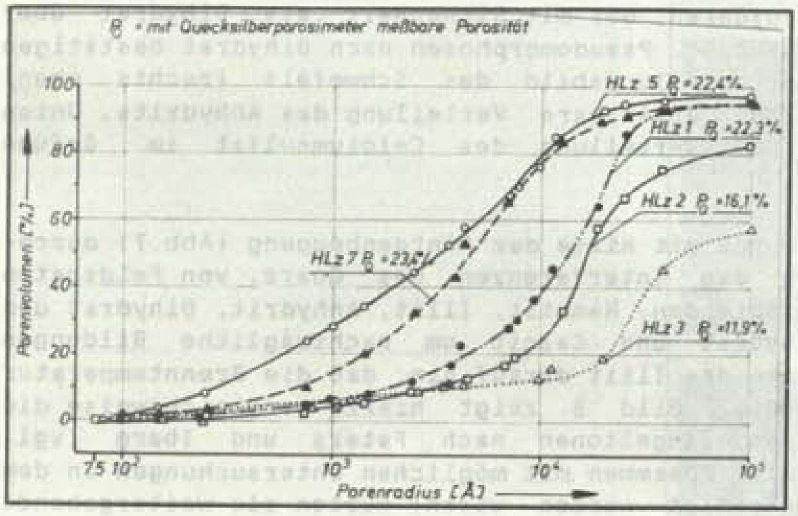


Abb.4 Porenverteilungen in Ziegeln

Die Heterogenität in der Ziegelmatrix wird auch aus der Abb.5 ersichtlich, in der ein Einschluß fester und dichter Substanzen in der sonst porösen Matrix festgehalten wurde. Die RMA-Flächenanalyse weist für das dichtere Material im wesentlichen einen höheren Na_2O- und Sulfatanteil auf.

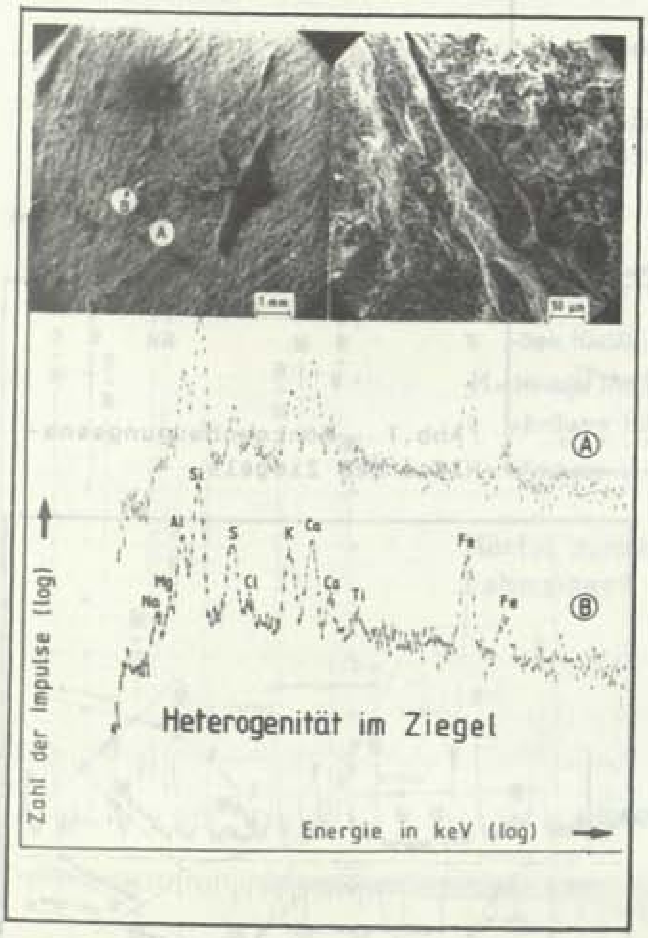


Abb.5 Heterogenität in der Ziegelmatrix

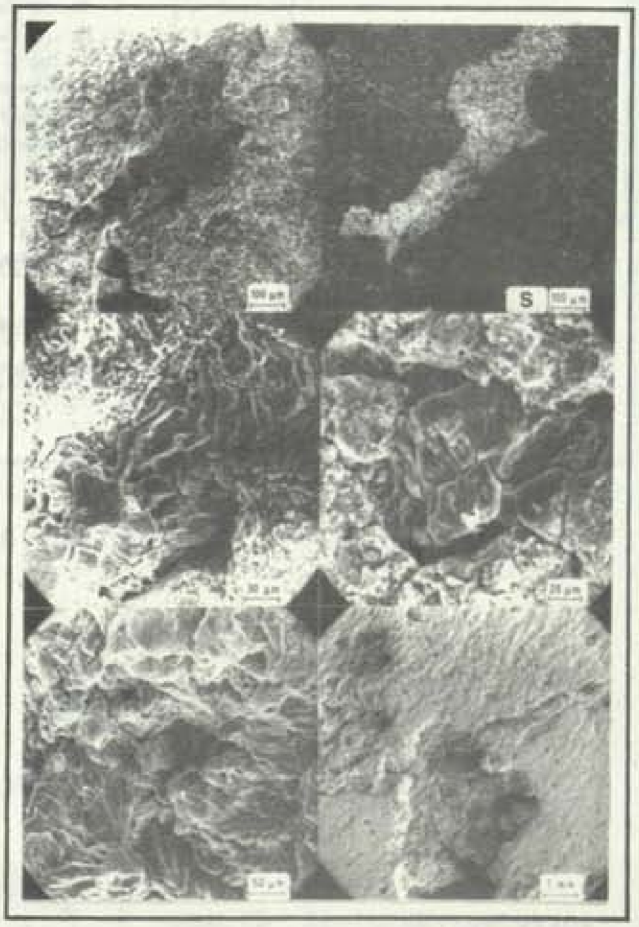


Abb.6 Sulfat in der Ziegelmatrix

Der Sulfatgehalt im Gefüge ist nach den vorliegenden Untersuchungen größtenteils auf vorhandenen Anhydrit zurückzuführen, der mit Sicherheit als Dihydrat über den Rohstoff eingebracht wurde (Abb.6). Pseudomorphosen nach Dihydrat bestätigen diese Hypothese. Das Elementverteilungsbild des Schwefels (rechts oben) bestätigt die bereits morphologisch erkennbare Verteilung des Anhydrits. Unten rechts wird die besonders grobe Verteilung des Calciumsulfat im Gefüge kenntlich.

Die Phasenanalyse des Ziegels wurde mit Hilfe der Röntgenbeugung (Abb.7) durchgeführt. Sie zeigt vornehmlich die Interferenzen des Quarz, von Feldspaten (Anorthit-Albit), Pyroxenen, Hornblenden, Hämatit, Illit, Anhydrit, Dihydrat und Calcit. Während es sich bei Dihydrat und Calcit um nachträgliche Bildungen handeln kann, weist das Auftreten des Illit darauf hin, daß die Brenntemperatur unter 950°C betragen haben mußte. Bild 8 zeigt hierzu vergleichsweise die Phasenumbildungen in kalkreicheren Ziegeltonen nach Peters und Iberg (vgl. Peters/Iberg 1978; Schmidt 1981). Zusammen mit möglichen Untersuchungen an dem Rohton, aus dem die Steine gefertigt worden waren, müßten sie weitergehende Aussagen über die Höhe der Brenntemperatur machen lassen. Aber auch Nachbrennversuche an dem vorhandenen Material könnten ausreichend sein.

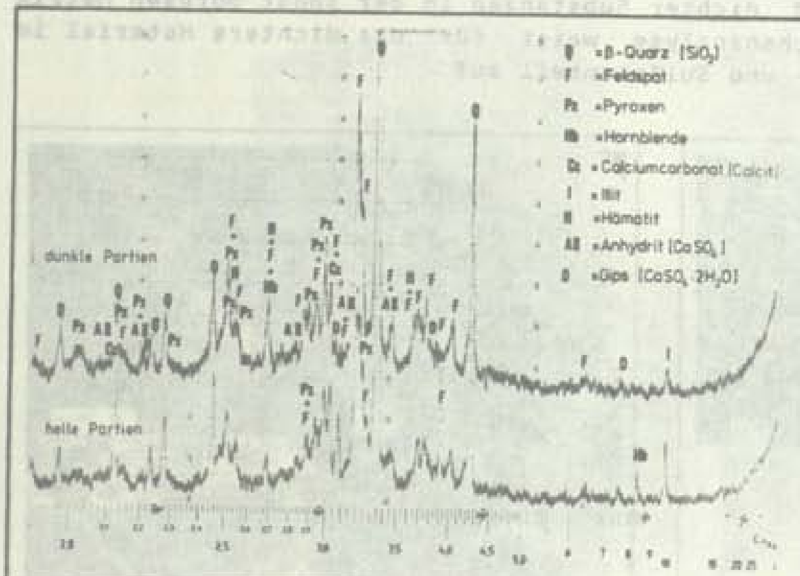


Abb.7 Röntgenbeugungsanalyse des Ziegels

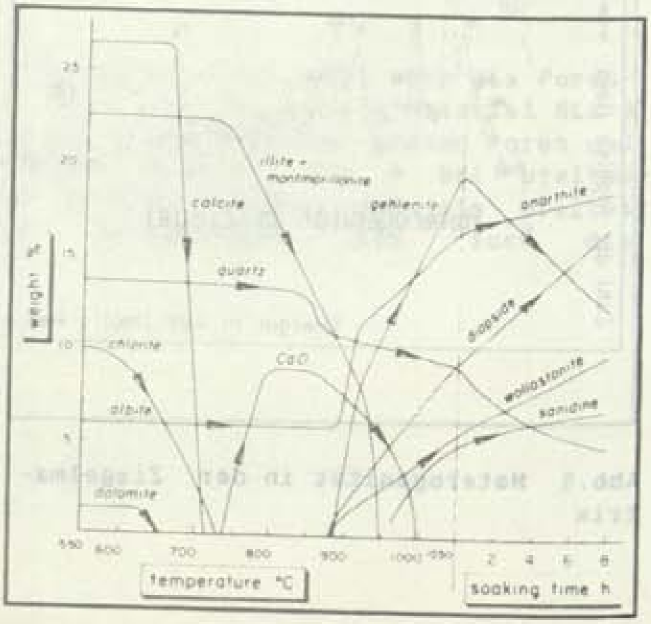


Abb.8 Veränderung in der Mineralzusammensetzung eines karbonatreichen Ziegelrohstoffes beim Brennen

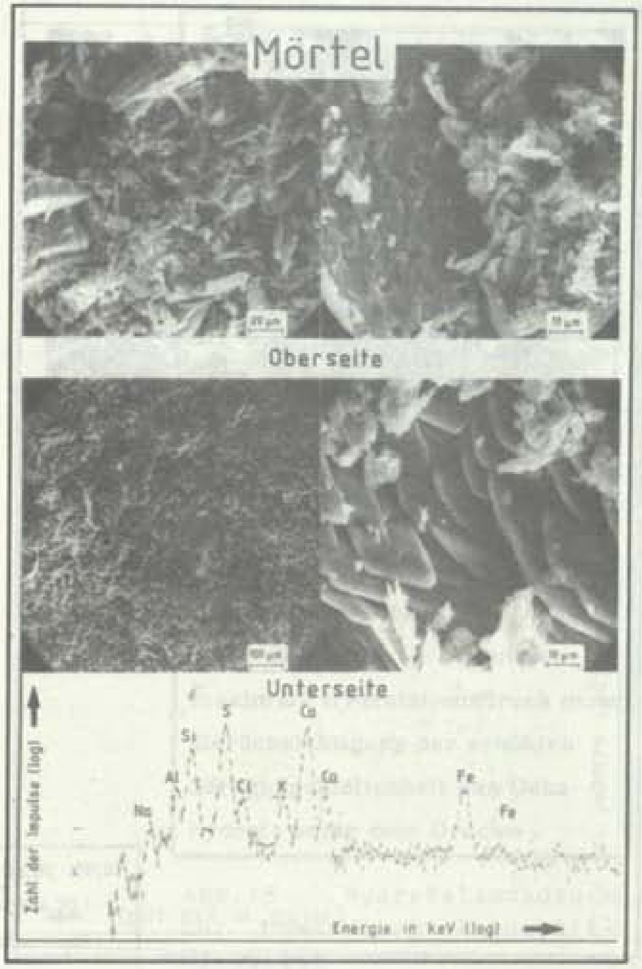


Abb.9 Mörtel zwischen Lehmziegeln

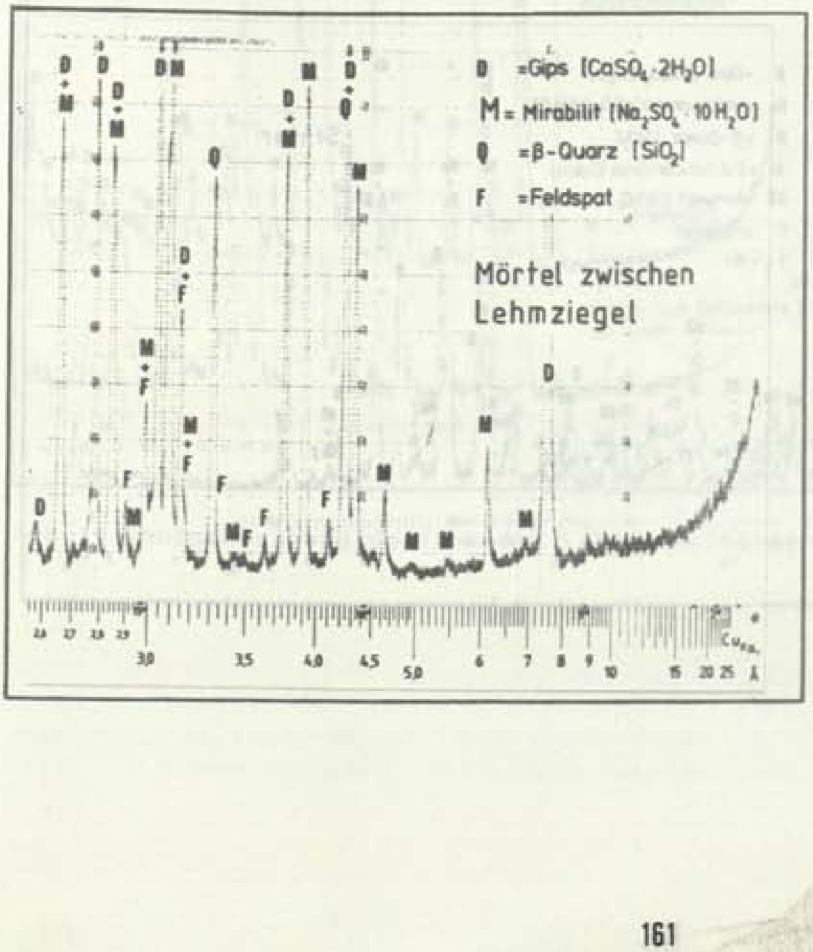


Abb.10 Röntgenbeugungsanalyse des Mörtels

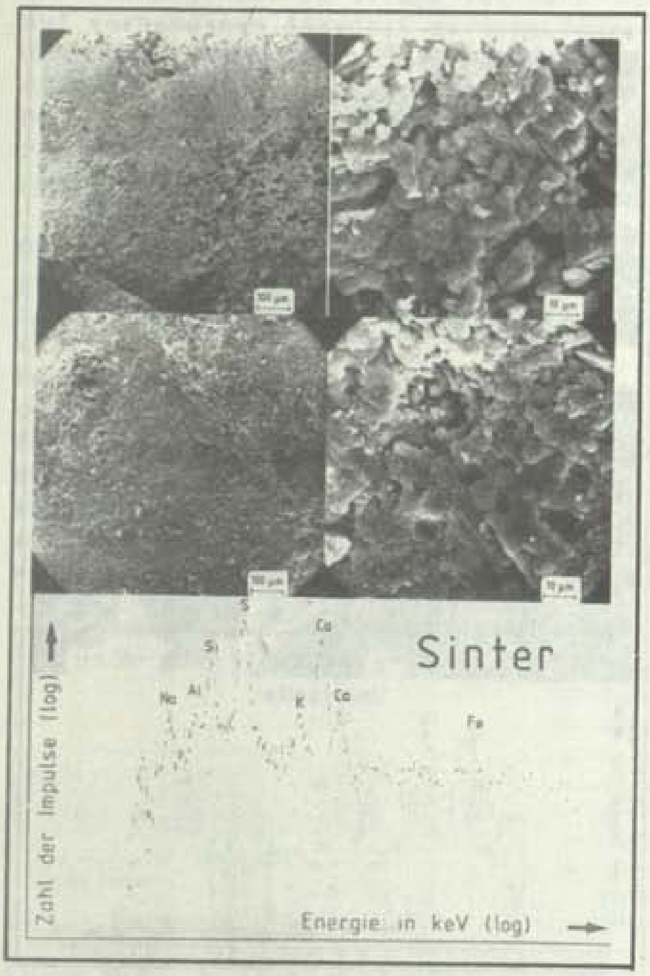


Abb.11
Sinter von der Ziegeloberfläche

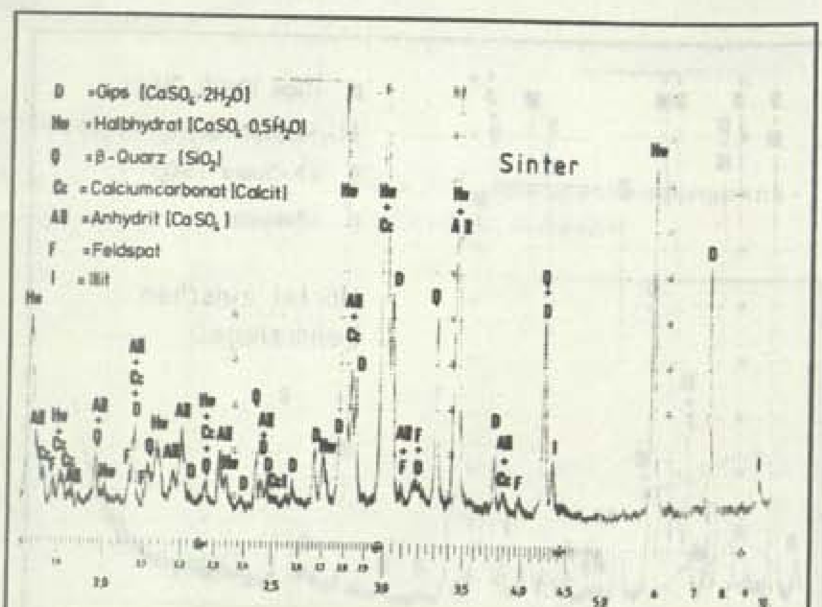


Abb.12 Röntgenbeugungsanalyse des Sinters

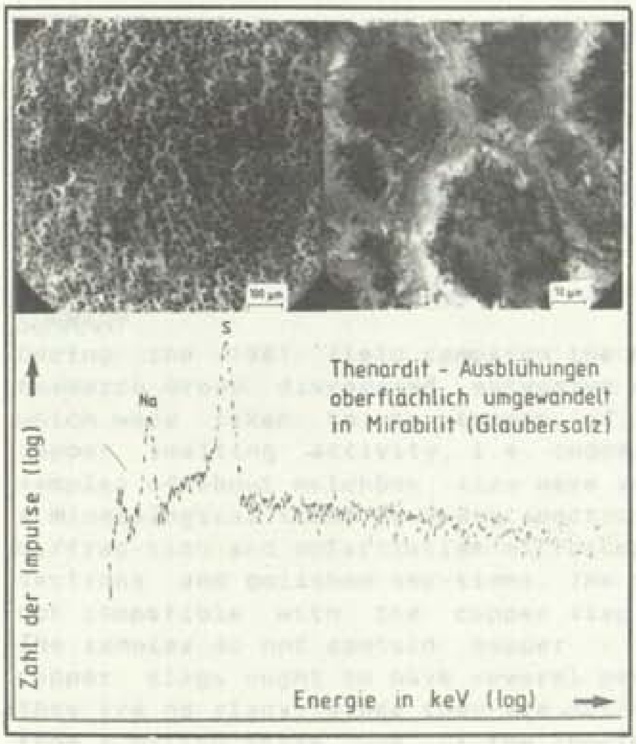
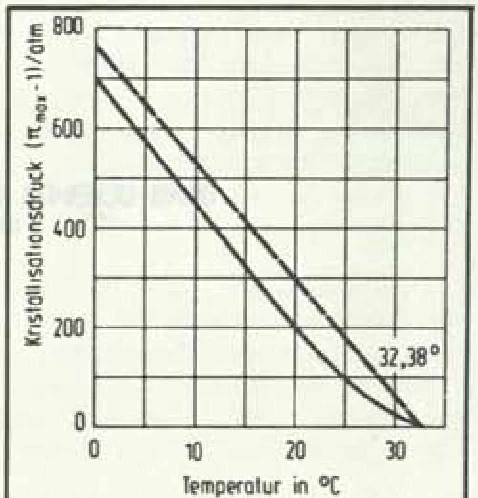


Abb.13 Salzausblühungen



Maximaler thermodynamischer Hydratationsdruck der Umwandlung $Na_2SO_4 \rightarrow Na_2SO_4 \cdot 10\,H_2O$ (—). Die Linie (----) ist der maximale Hydratationsdruck ohne Berücksichtigung der erhöhten Sättigungslöslichkeit des Dekahydrats unter dem Druck π.

Abb.15 Hydratationsdruck der Umwandlung Thenardit-Mirabilit

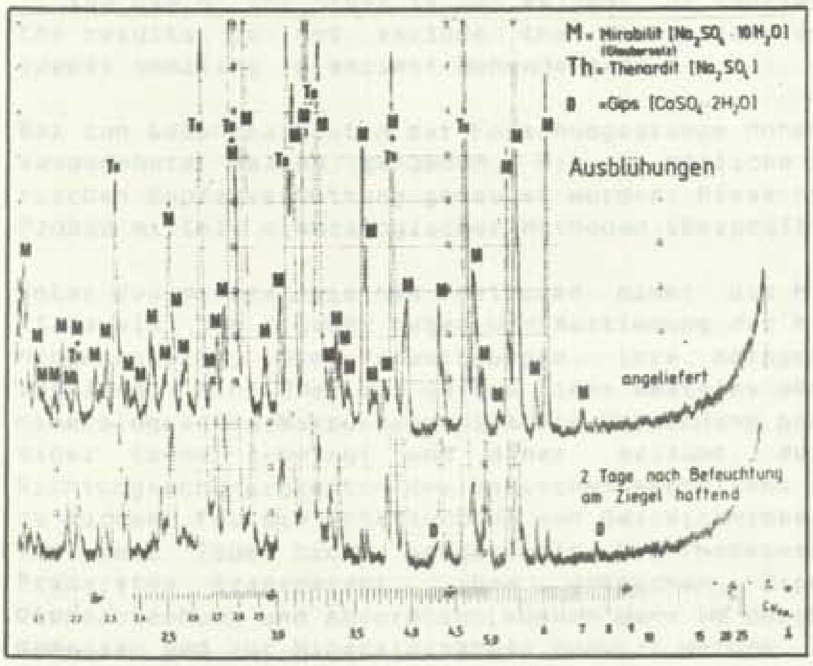


Abb.14 Röntgenbeugungsanalyse der Salzausblühungen

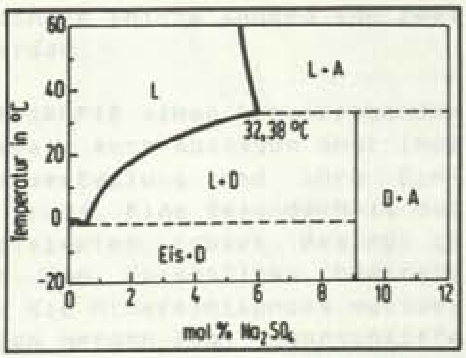


Abb.16
Schmelzdiagramm des stabilen Systems H_2O-Na_2SO_4
L= Sulfatlösung;
D= Dekahydrat; A= Anhydrit

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Bei den Geländearbeiten der Forschungsgruppe Mohenjo-Daro wurden im Jahre 1981 ausgedehnte Halden gefunden, die als mögliche Schlackenfelder einer prähistorischen Kupferverhüttung gedeutet wurden. Diese Hypothese sollte anhand von zwei Proben mittels mineralogischer Methoden überprüft werden.

Unter den mineralogischen Methoden nimmt die MIKROSKOPIE einen hervorragenden Platz ein. Sie erlaubt neben der Bestimmung der Minerale auch Aussagen über ihre Mengenanteile, ihre Verwachsungen, ihre Korngrößenverteilung und ihre Einregelung, d.h. über das Gefüge eines Gesteins oder Erzes. Eine Besonderheit der mineralogischen Mikroskopie ist die Verwendung polarisierten Lichtes, das nur in einer Ebene schwingt und daher erlaubt, durch den Kristallbau bedingte Richtungsabhängigkeiten des optischen Verhaltens für die Mineraldiagnose nutzbar zu machen. Für die Untersuchung von Gesteinsmineralien werden sog. Dünnschliffe von rund 25µm Dicke hergestellt. Die Gesteinsminerale werden in diesen dünnen Präparaten transparent, ihre optischen Eigenschaften wie Lichtbrechung, Doppelbrechung und Absorption können dann im durchfallenden Licht beobachtet und gemessen und zur Mineraldiagnose benutzt werden. Erzminerale sind i.a. bei 25µm Dicke noch opak und werden daher in Anschliffen mit reflektiertem Licht untersucht; hier sind die kennzeichnenden Eigenschaften insbesondere das Reflektionsvermögen (Helligkeit und Farbe des reflektierten Lichtes) und die relative Härte.

Sehr feinkörniges Material, das mikroskopisch nicht mehr bestimmt werden kann, wird mittels RÖNTGENDIFFRAKTION untersucht. Diese Methode beruht darauf, daß die Minerale aus regelmäßigen Atomanordnungen, den sog. Kristallgittern, aufgebaut sind, an denen Röntgenstrahlen quasi-reflektiert werden können. Dabei bestehen

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Probe 1 und die Probe 2 sind in ihrem Mineralbestand und im Gefüge auffallend ähnlich. Im Mikroskop sind reichlich bis millimetergroße Körner von Quarz und Feldspat (Plagioklas) zu erkennen, die in feinkörniger Matrix eingebettet sind. Ihre meist scharfkantige, nur teilweise gerundete Form zeigt, daß sie Trümmer präexistenter Minerale sind und nicht in der Matrix gebildet wurden (Abb. 3). Hämatit in Bruchstücken und feinsten Schüppchen vorhanden und verursacht die rötlich-bräunliche Färbung. Magnetit verrät sich in beiden Proben durch einen schwachen Magnetismus, sein Mengenanteil ist sehr gering und er ist nur mit stärkster Vergrößerung zu erkennen. In der grau-schwarzen "Übergangszone" der Probe 1 ist der Anteil der Matrix deutlich erhöht, darin treten massenhaft Blasen von wenigen µm Durchmesser bis zu mehreren mm Größe auf. Quarze und Feldspate sind z.T. angefressen und deutlich spärlicher als in der Kernzone vorhanden (Abb. 4).

Die röntgenographischen Analysen ergeben, zusätzlich zu den bereits im Mikroskop erkennbaren Mineralen Quarz und Feldspat, deutliche Anteile von Pyroxen (wohl Diopsid) und Glas, die offensichtlich nur in der feinkörnigen Matrix auftreten. Das Röntgendiagramm der "Übergangszone" (Abb. 5) zeigt dabei erhöhte Anteile von Pyroxen und Glas gegenüber der "Kernzone", entsprechend dem größeren Anteil der Matrix.

Die chemischen Analysen der Proben (Tabelle 1) stimmen so weitgehend überein, daß man für die Proben 1 und 2 gleiches Ausgangsmaterial anzunehmen hat. Die Veränderungen von Gefüge und Mineralbestand der "Übergangszone" von Probe 1 sind demnach durch thermische Beanspruchung ohne merkliche chemische Umsetzungen entstanden.

Im Zusammenhang mit weiteren Funden in der Umgebung kann die Schlußfolgerung gezogen werden, daß es sich bei beiden Proben um keramisches Material handelt. Probe 1 ist offensichtlich ein Bruchstück eines oberflächlich verglasten Steines aus der feuerseitigen Ausmauerung eines Töpferofens, Probe 2 läßt keinen Rückschluß auf ihre Verwendung zu.
Für Informationen über die Herkunft des Materials danke ich Herrn Dr.M.Jansen, für Röntgendiffraktometeranalysen Frau G.Siebel und für Röntgenspektralanalysen Herrn Dipl.-Min.J.Martin.

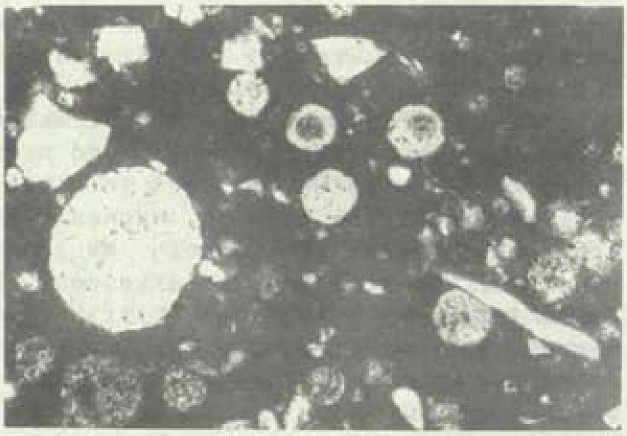

Abb.4
Probe1, schwarze Übergangszone; Dünnschliff 15783, 150fache Vergrößerung
Runde Blasen (hell- bis dunkelgrau) und meist kantige Quarzkörner (weiß) in dunkler feinkörniger Matrix.

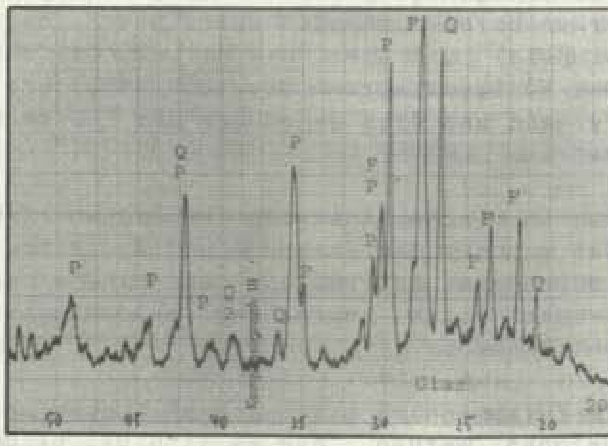

Abb.5
Probe1, schwarze Übergangszone;Röntgendiffraktometerdiagramm
Q = Quarz
F = Feldspat (Plagioklas)
P = Pyroxen

	Probe 1 (schwarze Zone)	Probe 1 (bräunliche Zone)	Probe 2
Fe_2O_3	5.77	5.95	5.56
MnO	0.11	0.1	0.1
TiO_2	0.78	0.76	0.71
CaO	8.84	9.04	8.05
K_2O	2.79	2.75	2.89
P_2O_5	0.18	0.66	0.25
SiO_2	60.7	59.44	59.96
Al_2O_3	14.35	14.58	14.01
MgO	3.44	3.35	3.42
Na_2O	0.88	0.87	1.27
	97.76	97.0	96.23

Tab.1

Abb.1
Probe 1, Querschnitt durch Ofenstein (Maßstab 5:1)
Dunkelgrau : schwarzgraue Übergangszone mit zahlreichen Blasen und hellen Mineraleinschlüssen
Weißgrau : glasige Deckschicht (oben)
Mittelgrau : bräunlich-rötliche Kernschicht

Abb.2
Probe 1, Ofenstein (Maßstab 3:1)
Draufsicht
Verglaste Oberfläche

Abb.3
Probe 2 (analog der Kernzone von Probe1), Dünnschliff 15783, 350fache Vergrößerung
Bruchstücke von Quarz (hell) und Feldspat (hell mit Lamellen), teilweise mit Reaktionssäumen, in feinkörniger Matrix (grau).

VERÖFFENTLICHUNGEN DES GEODÄTISCHEN INSTITUTES DER RHEINISCH-WESTFÄLISCHEN TECHNISCHEN HOCHSCHULE AACHEN

Nr. 1 JUNG, F.R.: Deutscher Landesbericht und Generalbericht der Kommission III (vermessungstechnische Instrumente und Methoden, Photogrammetrie, Kartographie) der Federation Internationale des Geometres (FIG) zum VIII. Internationalen Kongreß in Paris 1953. Resolutionen der Kommision III auf dem VIII. Internationalen Kongreß der FIG vom 28. August bis 6. September 1953 in Paris (1954)

Nr. 2 HEUPEL, A.: Ein Beitrag zur Ausgleichung größerer Höhennetze unter besonderer Berücksichtigung der bedingten Beobachtungen (Diss. 1958)

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Archalology — Mohenjo-Daro
Mohenjo-Daro — Archalology